University of Alberta

A Responsive Corporate Information Model

by

Lettice H. Tse

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Department of Computing Science

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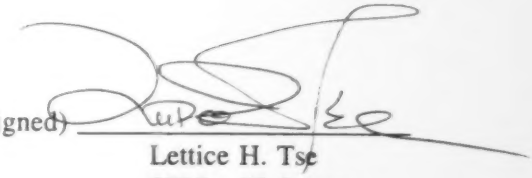
(Signed) 

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The undersigned certify that they have read, and recommend to the faculty of graduate Studies and Research for acceptance, a thesis entitled **A Responsive Corporate Information Model** submitted by Lettice H. Tse in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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In memory of my mother, Hon-Yuk Lau Lam

Abstract

A responsive approach to strategic management is required to deal with the frequency and urgency of the changes in today's dynamic organization environment. Effective information technology is needed to support management to promptly recognize and respond to critical changes. This thesis explores the issues and applicable planning concepts of strategic management in a dynamic environment. A responsive strategic management process is developed, together with a Responsive Corporate Information Model that supports the process. A prototype system is developed using the VisualWorks/Smalltalk Programming Environment and a RCIM is instantiated for an example organization. Several change scenarios are simulated to illustrate the capabilities and limitations of the model.

The major contributions of this research are:

1. Development of a responsive strategic management process.

Central to the philosophy of the responsive process is the recognition of the value of alternative action plans developed using a comprehensive planning process. These action plans represent viable approaches for accomplishing the organization goals and are formulated based on different resource requirements and different assumptions about the organization environment. These plans form the basis for focused environmental

monitoring activities and provide valuable information on possible alternative actions in response to the environmental changes.

2. Development of a Responsive Corporate Information Model (RCIM).

The RCIM extends prior research in information model in two aspects, namely, from a simple organization model to an in-depth model specific to the strategic management domain; and from a passive model to an active model through the use of active agents to support continuous environmental monitoring. The RCIM enables an organization to model its strategic plans, assumptions and indicators. Existing information systems resources are linked to the assumptions and indicators to support focused monitoring. Management, acting as the primary decision maker, can use the RCIM to systematically examine the objectives and action plans impacted by the changes, identify the alternative actions applicable to the situations, and select the best plans that make efficient and effective use of the organization's resources to attain its goals and objectives. Decision logging is built into the RCIM to support organization learning of the strategic decisions and decision making process.

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Chapter 1

Introduction

Today's organization is facing unprecedented challenges. Rapid technological advances and globalization of the economy translate into new rules and an expanded scope for an organization's business. The emphasis on total quality management, productivity improvement, and 'just-in-time' manufacturing precipitates business process restructuring and organization culture transformation. In this highly turbulent environment, management is increasingly reliant on information technology (IT) to assist in making decisions [Firdman 91, Frederick & Venkatraman 88, Sander 92, Gorry & Scott Morton 89]. However, historically, investments in IT have not always produced the expected benefits and promised tangible paybacks to the organizations [Clemons & Weber 90, Lederer & Sethi 92]. One major lesson learned by both IT professionals and business people is that IT, by itself, does not guarantee success if it is not understood and applied in the context of the organization's goals and strategies [Firdman 91, Fedorowicz & Konsynski 92, Gorry & Scott Morton 89, Lederer & Sethi 92, Lee & Leifer 92, Ward et al 90].

Numerous research works have investigated different ways of integrating organization goals and strategies with IT development and management efforts in order to take full

advantage of IT's strategic importance to the organization. Three particularly active research areas are executive information systems [Watson et al 91, Thierauf 91], strategic information systems [Firdman 91, Fredericks & Venkatraman 88, Cassidy 90] and information systems development methodology [Pohl & Jarke 92, Martin 87, Oivo & Basili 92]. Several important findings are evident from a review of the literature. Firstly, there is a definite correspondence between the goals of an organization and its information systems [Zviran 90]. Secondly, organization goals should be a key component of any corporate IT model that is used to guide the executive information delivery, strategic information systems design and information systems development effort [Ward et al 90, Chen et al 89, Sander 92, Volonino & Watson 91, Trippi & Salameh 89]. Such models focus the IT development and management effort towards organization effectiveness instead of on IT itself. This change in focus is required to enable IT to make a strategic impact on an organization. Thirdly, while existing corporate information models provide important insights into how information and IT can be organized to maximize their benefits to the organization, they do not actively support the dynamics in the organization environment [Fedorowicz & Konsynski 92, Kumar & Vrat 89, Trippi & Salameh 89].

The challenge of a dynamic environment demands a different management approach to cope with the frequency and urgency of the changes in the organization environment [Barney & Griffin 92, Cassidy 90]. In a stable organization environment, where changes are infrequent and low in urgency, the traditional strategic management approach focuses management attention on setting the goals, developing the plans and implementing the

selected plans. In a dynamic environment, management attention must be extended into monitoring the environment and taking prompt corrective actions in order to achieve the overall goals of the organization [Barney & Griffin 92, Cassidy 90]. We refer to the latter approach as the responsive strategic management approach and argue that such an approach requires the support of a new information model, a 'responsive' corporate information model. The increasingly turbulent organization environment presents a research challenge to investigate how an existing corporate information model can be extended to effectively assist management with detecting changes in the environment and responding to them quickly.

1.1 Motivation

Several factors underlie the direction and motivation to this research, namely, the potential benefits of IT support to the strategic management process, the potential benefits of modelling unstructured decisions, the maturity of IT in providing the opportunity to "model reality and manage complexity", and the need to capitalize on IT investments and to support change management.

Research on IT support for the strategic management process is important because effective strategic management is critical to the long term success of an organization. In a broader scope, this research also provides insights into how unstructured decisions in

other planning environments, such as software development, can be modelled. Strategic management involves unstructured or semi-structured decisions that deal primarily with infrequent, ill-defined problems. While IT support to structured business decisions, such as those relating to inventory control and accounts payable, have been successfully accomplished, the support to unstructured decisions is in greatest demand and provides the highest return on IT investment [Gorry & Scott Morton 89]. Explicit modelling of an unstructured decision was identified by Gorry and Scott Morton as an effective way of improving an organization's knowledge and experience with the decision making process. Improved understanding gradually transforms an unstructured decision into a structured decision, providing the opportunity for automation of the decision making process.

Current information technology is maturing rapidly and is now able to provide more effective support to organizations. IT advances in databases, open architectures, networking capabilities, and object-oriented system development contribute to flexibility in expressing information structure and information flow. In the 1990 ACM Conference on Critical Issues, the IT community was challenged to extend its interest beyond technology development into technology application and its effect on society [Frailey 91]. The need for IT support in two critical areas, modelling reality and managing complexity, was identified. This research is motivated by the belief that the key in addressing both issues lies in understanding the complexities of the real world and in being able to express them in appropriate information models so tools and methods can be configured to analyze and manage the complexities.

At the same time, it is recognized that many organizations have made significant IT investments over the last few decades. Capitalization of these IT investments is important. In view of shrinking information systems development budgets and difficult economic climate, large scale system re-development is unrealistic. Any proposed IT solution to support the responsive strategic management approach must effectively incorporate existing IT resources in the organization and provide a migration and expansion path to such incorporation.

The emphasis on the dynamic aspect of the organization environment is also motivated by the critical need to better understand the management of change. It is paradoxical that "the only constant in today's world is the presence of change". Issues relating to planning in a dynamic environment are common in other areas eg. software development. Lessons learned from this research should provide insights to other dynamic planning environments.

1.2 Thesis Context

The basic research questions addressed in this dissertation can be summarized as:

1. What are the characteristics of a dynamic organization environment and what are the problems with strategic management in such an environment?

2. What design concepts in other research disciplines may be applicable or adaptable to

an information model designed to support strategic management in a dynamic organization environment?

3. Is it possible to utilize existing IT resources within the proposed information model to support strategic management so as to reduce the system development effort and to realize the benefits within a reasonable time?

The Responsive Corporate Information Model is developed in response to these research questions.

It should be noted that this research is anchored on several basic management principles. Firstly, well-formulated and well-communicated goals are critical to the success of an organization [Barney & Griffin 92]. This principle is well-supported in the total quality management (TQM) approach to management [Cartin 93] and the success of Japanese companies [Tobin 90]. Secondly, the primary responsibility of management is to co-ordinate the organization's effort to achieve the overall organization goals [Barney & Griffin 92]. This principle is the foundation of strategic management research effort and practices [Dean & Cassidy 90]. Thirdly, where possible, executives rely on information to make decisions [Ojha & Brown 93]. Management by intuition, where decisions are made based on adhoc use of incomplete, inconclusive, and contradictory information, occurs by necessity, not by choice. If executives have available to them the right information in usable format, they will use the information in making their decisions. This principle is fundamental to the research effort on strategic information systems and executive information systems.

1.3 Research Scope and Limitations

This research is carried out in three separate phases. Phase 1 is a literature review to identify the issues of strategic management in a dynamic environment and the planning concepts applicable in such an environment. The review concludes with the development of a normative (or prescriptive) responsive strategic management process and the identification of the requirements for an information model to support the process. Phase 2 includes the development of a Responsive Corporate Information Model (RCIM) and the development of a prototype system that makes use of the model to support a responsive strategic management process. Phase 3 involves the use of the prototype system to instantiate a Responsive Corporate Information Model for an example organization and the simulation of several changes commonly found in an organization environment. The exercise is used to illustrate the operation of the RCIM and to analyze its capabilities and limitations. The example organization used is the Information Technology Research Institute of the Department of Computing Science, University of Alberta. Information from the strategic and business plans developed for the Institute in 1992 is used in the scenarios.

Two limitations of this research are noted:

1. Limitation of the Responsive Corporate Information Model

Strategic management includes three chronological phases, namely, the goal-setting

phase, the strategic planning phase and the management control phase. The goal-setting phase covers the setting of goals and overall strategic direction. The strategic planning phase covers the setting of short-term objectives, the development of action plans and the allocation of resource for plan implementation. The management control phase covers the monitoring of plans and the organization environment, and the implementation of corrective actions. The benefit of the RCIM support is primarily captured during the management control phase, but the information necessary to support this phase is defined and assembled during the other two phases. The current research focuses on the feasibility and potential benefits of the RCIM support. Although some discussions on the methods and tools to support the data capture are included, the issues of human-computer interface for executive tools are not fully explored. Further research in this area is required to make the RCIM a more effective executive management tool.

2. The use of an example organization instead of a real operating organization to study the instantiation and simulation of the model

The decision to use the Information Technology Research Institute (ITRI) as an example organization to illustrate the modelling and operation of the Responsive Corporate Information Model (RCIM) is recognized as a limitation of this research. Ideally, a field test, applying the model in an operating organization, will provide more insights and feedback to the research. However, the scope and

duration of such a field test is beyond that of a PhD dissertation. Furthermore, some scenarios to illustrate the concepts and benefits of the model are necessary before a candidate for the field-test can be found. The use of the ITRI has the advantage that most of the information required for the RCIM such as goals, objectives, action plans, indicators, etc. are available. The strategic plan and business plan were developed with the support of the Research Planning and External Relations Committee of the Department of Computing Science. The plans were reviewed and approved by the Executive Committee of the Department, the Department Council and the Industrial Advisory Committee of the Department. Therefore, the strategic planning information and the process used are believed to be realistic and valid enough for use as an example in this dissertation. The use of an operating organization to further study the concepts and operation of the model is suggested for future research.

1.4 Overview

The organization of this thesis follows the three phases of the research. Chapter 2 summarizes the literature review which covers related research in reactive reasoning and planning concepts, executive information systems, decision science, management science, organization learning, and information systems modelling. Chapters 3 and 4 describe the Responsive Corporate Information Model (RCIM) and the prototype system development

respectively. Chapter 5 uses the ITRI data to illustrate the modelling capability of the Responsive Corporate Information Model and the operation of the prototype system. The thesis is concluded in Chapter 6 with a discussion of the contributions of this research and future research plans.

Chapter 2

Review of Literature

In this chapter, research in several areas are reviewed in order to establish the conceptual basis for the responsive strategic management process and the architecture and operation of the Responsive Corporate Information Model (RCIM). Section 2.1 is an overview of the strategic management process in a dynamic environment. It characterizes the environment and introduces the concept of responsive strategic management. Section 2.2 describes the dynamic environment in which autonomous robots operate and the reactive reasoning and planning concepts that have been used in the control of these robots. The adaptability of these concepts in an organization setting is then discussed. Section 2.3 reviews the organization practice of environment monitoring and how executive information systems can be incorporated to support the strategic management process. Section 2.4 reviews research relating to decision support in a dynamic environment in order to fine tune the adaptation of the reactive reasoning and planning concepts in an organization setting. Section 2.5 discusses Business Process Re-engineering (BPR) concepts within the context of responsive strategic management. BPR has been looked upon by many organizations as a means of gaining competitive advantage in the 1990's. The discussion shows how the proposed RCIM can be adapted to support the BPR

projects. Section 2.6 discusses research work in integrated organization and information systems modelling which provide the foundation material to the development of the RCIM. Section 2.7 summarizes the key findings from the research review to form a basis for the concepts behind the Responsive Corporate Information Model.

2.1 Overview of the Strategic Management Process in a Dynamic Environment

Strategic management is a management process directed at combining resources effectively and efficiently in order to attain the organization's goals [Barney & Griffin 92]. Generally speaking, the process can be divided into three phases, namely, the goal-setting phase, the strategic planning phase, and the management control phase.

Goal Setting Phase

Periodically, an organization undertakes a major initiative to re-examine its mission, goals and strategies. Such a major undertaking may occur at the start up of the organization; it may be scheduled once every five to ten years; or it may be the result of drastic changes in the organization environment such as loss of major market shares, a new CEO, major change in consumer purchase patterns, etc. In these situations, an organization needs to define (or re-define) its mission (ie. the fundamental reason for its existence); its strategic goals (ie. the vision of what it should and can accomplish); and its strategies (ie.

the approaches for accomplishing its goals). The focus is on long term planning, on setting the direction of the organization and on overall resource allocation [Barney & Griffin 92].

The goal-setting phase is often carried out by a small group of senior management and involves iterations of intensive discussions with input from the rest of the organization. Goals serve several important functions in the organization. They provide guidance, unify direction, facilitate planning, motivate and inspire employees, and aid in evaluation and control. Setting challenging and yet achievable goals is crucial to the success of an organization. A delicate balance of innovation and conservatism needs to be maintained. A wide range of factors such as current company state, customer requirements, industry structure and threat of competitors are considered in the process of establishing a realistic vision of what the organization should strive to become.

Strategy has been defined as "the pattern or plan that integrates an organization's major goals, policies, and action sequences into a cohesive whole" [Mintzberg & Quinn 91]. Each strategy is selected to present the organization with the greatest possibility of success, given the specific opportunities and risks within the environment, and the specific strengths and weakness of the organization [Hosmer 82]. In other words, strategies are selected through a comprehensive process to guide the organization in the development of its strategic plan. The selected strategies identify specific areas in the business that the organization must focus on. For example, critical success factors identify the few key

areas which, if results are satisfactory, ensure successful competitive performance for the organization [Rockart 79].

Once goals and strategies are set, it is important that they be communicated to the entire organization for evaluation and feedback. Studies have found that organizations that involve their employee's input during the goal setting stage and take the effort to communicate the goals to the employee are more successful in generating the overall organization's commitment to accomplish the goals.

Strategic Planning Phase

During the strategic planning phase, long term goals are translated into action plans. Collectively, goals define management's vision of ***what*** the organization should achieve. This vision needs to be casted within a timeframe (the ***when***) for realization. This timeframe is referred to as the planning horizon: the period of time over which an organization's plans apply. Objectives refine organization goals within the planning horizon into more specific and measurable targets. In other words, goals define the overall direction and viability of the organization and objectives define the supporting short term targets for which measurable results can be obtained [Barney & Griffin 92]. The shorter time span of the objectives allows for the formulation of more specific action plans and the close monitoring of the progress towards the goals. Action plans address ***how*** the goals and objectives can be achieved.

Typically, the entire organization participates in the strategic planning process. Proposals are developed identifying action plans to accomplish the goals. These proposals may represent initiatives from various levels of the organization hierarchy or they may be directives from the senior management. While expertise and experience of the organization in problem solving are important in the formulation of the proposals, innovative ideas are often necessary in order to accomplish challenging goals [Barney & Griffin 92]. The nature of strategic planning therefore carries with it a degree of exploration and uncertainty.

Usually, more than one action plan is proposed to accomplish a goal. Each plan is developed based on a set of implicit/explicit assumptions about the conditions in the organization environment and a set of resource requirements. The number of alternative action plans and the details of the assumptions depend on the expertise and experience of the organization in addressing the particular goals and objectives. The viability (feasibility) of all proposed action plans are assessed by senior management or, more often, by strategic planners under the direct supervision of senior management. The assessment is often based on anticipated environmental conditions. All viable alternatives for accomplishing the goals are then evaluated against a pre-defined set of criteria in order to select a set of action plans for implementation. Since the effective and efficient allocation of resources is a prime concern of management, the evaluation often consists of a cost/benefit comparison of the proposed action plans in order to select a set of action plans that together require the most optimum use of resources to accomplish all the

organization goals. The set of selected action plans is referred to as the ***strategic plan*** of the organization. The consideration of the set of selected plans as a cohesive whole is crucial [Mintzberg & Quinn 91, Kumar & Vrat 89]. The cohesiveness implies that changes that directly impact the viability or resource requirements of one of the selected action plans may indirectly impact the entire set of selected plans. The inter-dependencies of the selected action plans must be addressed in the management of the plans.

Management Control Phase

Once the strategic plan is selected, an organization proceeds onto the implementation of the action plans. Resources identified in the proposals are committed and individual units or departments are given the responsibility to implement the proposed action plans. Typically, one or more related action plans are grouped into a project and the accountability for the successful completion of the project is delegated to the individual project manager or department manager. A periodic evaluation system is put in place to keep sen or management abreast of the progress. Indicators are identified to provide quantitative measure of the organization progress. If the progress is unsatisfactory, corrective action plans are devised in order to deliver the planned results. These corrective actions often involve commitment of additional time, money and resources. The overall intent is to ensure the successful accomplishment of all individual projects (ie. all selected action plans), in order to accomplish the overall organization goals.

Implication of a Dynamic Environment

Research suggests that a comprehensive strategic management process, similar to the one described, is only suitable for a stable environment [Frederickson 84, Frederickson & Mitchell 84]. A comprehensive process emphasizes complete information acquisition, rational calculation and participation from all individuals in the organization. Since the strategic plan is selected based on a set of anticipated conditions about the organization environment, the success of the plan depends on the assumptions being valid and on the individual action plans performing as anticipated. In a dynamic environment, complex, fast moving changes threaten the continuing viability of the organization's strategic direction (ie. goals and strategies) and the individual action plan. The urgency of the change (measured in terms of the relative time from the development of the change to impact) is often more critical than the magnitude of the change since it reduces the time for management to respond [Cassidy 90]. An individual action plan often becomes irrelevant before it is implemented. Corrective action plans, developed in haste, often lack the comprehensiveness of the original action plans. Escalation of commitment (referring to the commitment of additional resources, time and effort to a failed plan without proper evaluation of the continual relevance of the plan) often leads to ineffective and inefficient use of resources. The constant changes in the environment quickly render the selected plans irrelevant and the benefits of the comprehensive planning process lost.

A noncomprehensive or incremental planning process has been suggested as more

applicable in a dynamic environment [Frederickson 84, Frederickson & Mitchell 84]. The process generates plans that provide a general organizational direction for a short time and then replaces them with other plans. The shorter time frame reduces the impact of environmental changes to the relevancy of the plan. The planning process is less complete, collects less information, involves fewer individuals and expends fewer resources. As a consequence, the organization is able to adjust to changes more rapidly. However, the same research points out that comprehensive planners outperform noncomprehensive planners in a stable environment, suggesting that the comprehensive approach generates a more effective strategic plan.

Herein lies the challenge of strategic management in a dynamic environment:

> "Using a comprehensive planning process, is it possible to develop a strategic plan that can withstand the effect of changes in the dynamic environment?"

The author believes that it is possible and proceeds in this dissertation to demonstrate the feasibility of such a plan. The key to such a plan is the expansion of the scope of the plan from the set of selected action plans to the set of all strategic alternatives identified throughout the life cycle of the strategic management process; and to consider the set of selected action plans as representing only the action plans that the organization intends to implement if the anticipated conditions in the environment holds true. Management of such a strategic plan requires IT support, a key component of which is the proposed

Responsive Corporate Information Model (RCIM).

For ease of discussion, the term ***responsive strategic plan*** is used to refer to a strategic plan that is developed using the comprehensive planning process and can withstand the effect of changes in the dynamic environment; and the term ***responsive strategic management process*** is used to refer to the process to develop and manage such a plan. The term ***strategic alternative*** is used to refer to any action plan and objective identified throughout the strategic management process.

In the remainder of Chapter 2, literature reviews from different research areas are summarized in order to establish the conceptual basis of the responsive strategic plan and the RCIM. However, the responsive strategic management process is briefly introduced here to provide a framework for the discussion.

Introduction to a Responsive Strategic Management Process

Within a responsive strategic management process, an organization uses the comprehensive planning process to develop multiple strategic alternatives for accomplishing its overall goals. The set of all proposed strategic alternatives forms the initial responsive strategic plan. Based on the anticipated conditions in the environment and the estimated resource requirements of the alternatives, a subset of the alternatives is selected for implementation. During the management control phase, the organization

actively monitors the environment to ensure that the selected alternatives remain viable and resource efficient. At the same time, new strategic alternatives may become available as a result of management or technology improvement. These new opportunities are explored using the same comprehensive planning process and are incorporated into the responsive strategic plan as they become available. Previously non-viable strategic alternatives may also become viable as a result of changes in the environment and are made available for selection. If changes impact the viability of any selected action plans, instead of developing corrective action plans to restore the viability of the impacted action plans, the organization can choose to review all viable strategic alternatives in the responsive strategic plan and select a new set of strategic alternatives for continued implementation. In essence, the responsive strategic plan remains open and flexible within the dynamic environment and the organization remains focused on accomplishing the overall goals instead of a set of selected strategic alternatives.

The management of such a responsive strategic plan is not trivial. The number of strategic alternatives that can be identified to accomplish the overall goals and the scope of the assumptions and resource requirements associated with these alternatives represent a significant amount of information. The complex relationships between the goals and strategic alternatives must be maintained in order to support the ongoing evaluation and selection of a new set of strategic alternatives for implementation. The direct and indirect impact of the environmental conditions to the strategic alternatives must be captured. The urgency of the environmental changes imposes stringent demands on the response time

available for the review and re-selection of the alternatives. IT support is critical in the successful management of the responsive strategic plan.

The Responsive Corporate Information Model (RCIM) is proposed as the key component of the IT support for the responsive strategic management process. Specifically, the model allows an organization to represent all components of the responsive strategic plan, ie. the goals, objectives and action plans that are generated during the strategic management process; and the complex relationships among these components. In addition, the model supports a systematic approach for selecting a set of strategic alternatives to implement. Since the selection criteria includes the viability of the strategic alternatives and the resource requirements, the model also captures the assumptions and resource requirements of the strategic alternatives and the impact of any environmental changes.

The conceptual basis of the responsive strategic management process and responsive strategic plan is largely adapted from the reactive reasoning and planning concepts used in the control of autonomous robots operating in dynamic and hazardous environments. Research work in management information systems (specifically executive information systems and decision support systems) and management sciences (more specifically environmental monitoring and decision support) are examined to "fine tune" the adapted concepts for use in the organization environment. Modelling concepts used in the development of the RCIM are based on research on integrated organization and information systems. The remainder of this chapter is devoted to the formulation of these

conceptual bases. A summary of the findings is provided in Section 2.7.

2.2 Reactive Reasoning and Planning Concepts

Reactive reasoning and planning concepts are now commonly used in designing control systems for autonomous robots operating in dynamic and hazardous environment. "Reactive" refers to behaviour in response to changes in the environment. Research in robotic control shows that robots like Shakey [Nilsson 84], with control systems designed using the traditional AI planning approaches, are not reactive enough (ie. do not provide fast enough response to changes in the environment) for the demands of the dynamic environment [Sahota 94]. Traditional AI planning approaches consist of distinct plan construction and plan execution phases. During the plan construction phase, inference rules and knowledge about the environment are used to formulate a comprehensive plan to achieve a prescribed goal. The complete plan, composed of detailed actions, is passed onto the plan execution phase where the detailed actions are performed successively to completion. The effectiveness of such a planning approach depends on several conditions [Georgeff & Lansky 87]. First, all information necessary for comprehensive planning is available at the start of the plan construction phase. Second, the environment remains static throughout the two phases so that the goal and the corresponding plan remain valid. Third, enough time is available for the construction of the comprehensive plan and its execution. Unfortunately, these conditions are not assumable in a dynamic environment.

Failure of robots like Shakey led to research in reactive reasoning and planning design concepts that dealt specifically with the issues of planning and operating in a dynamic environment.

A number of reactive reasoning and planning systems have been developed [Brooks 86, Agre & Chapman 87, Firby 89, Gat 92, Kaelbling 87, Sahota 93, Georgeff & Lansky 87, Mitchell 90, Vercelli et al 94, Langer et al 94, Zelinsky & Yuta 93, Lopez 93, Miura et al 93, Haas 92]. Informally, the systems can be classify into ***strictly reactive systems***, ***reactive planning systems*** and ***reactive-and-planning systems*** according to their interpretation of reactivity and planning.

Strictly reactive systems are designed to be highly reactive to external stimuli. Input from the robot's sensors trigger reactive actions from the hardware executor. The design decision to avoid explicit representation of the robot's environment prohibits sophistication in planning [Sahota 93, Haas 92]. Example of these systems include robots designed with the subsumption architecture [Brooks 86, Brooks 91] and the concrete-automata architecture [Agre & Chapman 87, Haas 92]. While these systems may be useful in some robotic problem domains, they have been criticized for their lack of "intelligence": intelligence being related to the ability to anticipate problems and plan ahead [Sahota 93]. The lack of planning sophistication limits their application in an organization management setting.

Reactive planning systems exhibit a more intelligent reactive behaviour. Information scanned from the environment is assessed against and integrated with knowledge captured in an internal environment model. Plans for achieving specific goals are pre-defined by the system designers and are selected for execution based on conditions contained in the environment model. The ability to select alternative actions in response to different conditions in the environment underlies the reactivity of these systems. Example of these systems include the Procedural Reasoning Systems (PRS) [Georgeff & Lansky 87], ATLANTIS [Gat 92], and the Reactive Deliberation System [Sahota 94]. One criticism of the reactive planning system is their dependence on pre-defined plans. What happens if the robot is faced with a situation that is un-anticipated by the system designers and no pre-defined plan can be found to match the conditions in the environment model?

The ***reactive-and-planning systems*** attempt to address these situations by combining other AI planning approaches and reactive planning into one hybrid planning system. An example of these systems is the Theo-Agent system [Mitchell 90] which is designed to "react when it can, plan when it must, and learn by augmenting its reactive component whenever it is forced to plan". If the Theo-Agent system can find a pre-defined plan that matches the existing conditions in the environment model, the plan is selected for execution. Otherwise, traditional planning takes over to build a plan. The new plan, together with the prevailing conditions, are then stored for future use. Other examples of reactive and planning systems include NAVNEX [Vercelli et al 94] and MRG [Traverso et al 94]. It is noted that there is no agreed upon design concepts or architectures for

reactive planning systems, the choice often depends on the design goals and the robot's hardware limitation [Sahota 94].

The research goal in this dissertation is to explore concepts that can assist management to deal with the issues in a dynamic environment. We are primarily interested in concepts that answer questions like: how should strategic plans be formulated so that they remain reactive (flexible) to changes in the environment; how can the impact to the plans be identified with respect to impending environmental changes; how can critical changes be distinguished from non-critical ones?

In many ways, today's organization environment is similar to the dynamic environment in which the autonomous robot typically operates, and the decision making process facing management is similar to that required of the robot. The unavailability of complete information at the start of the planning cycle, the need for timely response, the interruption of unexpected critical situations exist in both environments. It is therefore conceivable that the design concepts that work successfully for the reactive reasoning and planning system in robot control can be adapted for use in the organization management setting. Review of the reactive reasoning and planning systems identifies several commonly used concepts, namely, the partial-planning strategy, the planned perception concept, the use of predefined plans, the interruptible transient goal management, and the partitioned architecture. These concepts are described separately and their adaptation to the strategic management setting is discussed.

Partial Planning Strategy

A partial-planning strategy describes an approach that focuses on identifying the 'what to do' in accomplishing a given goal from the 'how to do it' [Georgeff & Lansky 87]. Given a goal, a partial plan consisting of a sequence of subgoals is first formulated, laying out the "what's" that must be accomplished to achieve the goal. Plans for accomplishing each subgoal are also defined in the system. Several alternative plans may exist for a subgoal, each plan being associated with a unique set of environmental conditions applicable to it. A plan can be a single action performable by the robot's hardware or another high-level plan consisting of other subgoals. Each plan is stored with the set of environmental conditions applicable to it. The choice of the actual actions, the 'how's", for each subgoal is deferred to a time as close to execution as possible. The deference enables the system to take advantage of new information that becomes available in the environment in making its choices, while the high-level plan ensures the continual pursuit of the original goal. Similar planning strategies are found in other reactive planning systems such as ATLANTIS [Gat 92] and Reactive Deliberation System [Sahota 93]. The partial planning strategy is credited as the key concept behind the reactivity of these systems [Georgeff & Lansky 87]. The decomposition of the goal into successive levels of subgoals and plans provides an architectural structure to support the interleaving of the environmental monitoring and the plan execution processes described later under the subheading of interruptible transient goal management. The reactive capability of the system depends on the extent to which goals are decomposed. As more alternatives and environmental

conditions are identified, the selection of the executed plan will be more precise. The emphasis on the "what-to-achieve" instead of the "how-to-achieve" encourages a more detailed analysis at the planning stage and a more thorough exploration of alternatives and assumptions.

The partial planning strategy is the key reactive reasoning and planning concept that influences the formulation of the proposed responsive strategic plan. It points out the significance of retaining all alternative subgoals and plans as components of an overall reactive plan to support the reactivity of the robotic control system. The relationship between the reactivity of the overall plan and the extent of the decomposition has significant implications for the strategic planning process and the responsive strategic plan. Traditionally, strategic proposals are developed as detailed action plans. To be reactive, the comprehensive strategic planning process needs to focus on identifying the intermediate objectives that connect the action plans and the goals to be accomplished.

Planned Perception Concept

Continuous environmental monitoring is vital for a robot to keep abreast of its environmental conditions. Robot sensors scan the environment continuously. Data collected by the sensors must be assessed against and integrated with the existing knowledge in the system, and made available immediately to influence the selection of the alternative action plans. The complexity of the real world necessitates guidance to the

robot sensors so that they can scan and capture the information crucial to the task on hand.

Planned perception is a concept for abstracting a set of environmental information to be monitored [de Compos and Monteiro de Macedo 92]. The concept consists of a two-phased cycle. During the first phase, a perception plan is composed by examining the perception opportunities applicable to the tasks on hand. This perception plan is executed during the next phase; and its execution is monitored and updated to reflect the conditions in the environment. In essence, reactive planning is not only applied to the motion of the robot but also to environmental monitoring, enabling a more focused monitoring and interpretation of the relevant information.

In an organization environment, bounded rationality limits the amount of information senior management can process in decision making. Environmental monitoring needs to be focused on a set of crucial indicators recognized as having significant impact to the strategic plans. This set of indicators needs to be updated as the environmental conditions change. A flexible environmental monitoring plan is necessary. In Section 2.3, the organizational practice of environmental monitoring and existing IT support for it are explored in order to determine how the planned perception concept can be incorporated into the design of the responsive strategic plan.

Use of Pre-defined Plans

A reactive planning system typically makes use of pre-defined plans to achieve a faster response time. Instead of using inference rules and environmental data to develop a plan, the system uses the environment data to identify suitable pre-defined plans in its database for accomplishing the goal. These plans are either pre-defined by the system designer [Georgeff & Lansky 87] or previously developed by the system for similar environmental condition [Mitchell 90]. Each plan is stored in the database together with information regarding the goal or subgoal that it can achieve and the environmental conditions for which it can be selected. Pre-defined plans encapsulate the experience and expertise of the reactive planning system in solving problems in a similar situation. The ability to recall and "reuse" the experience from a similar situation has been experimentally shown to drastically reduce the response time in the Theo-Agent System [Mitchell 90].

In an organization environment, the concept of pre-defined plan is quite applicable. Current management science theories and practices are far from being able to sustain the use of traditional AI planning approaches to generate comprehensive plans. Precise inference rules often do not exist. Strategic alternatives are plans pre-defined by the organization to achieve the goals. The environmental conditions necessary for the plans to be viable are often identified as part of the documentation for the plans. The basic information necessary for building the responsive strategic plan is therefore readily available.

The inability of current management technology to automate the strategic planning process as a rule-based system also implies that the hybrid planning approach used in a system like Theo-Agent cannot be directly adapted to handle unanticipated environmental situations. Alternative means must be employed to alert management to the unavailability of pre-defined plans for the situations; to facilitate analysis of the situations-on-hand; and to prompt for additional corrective action plans. In this dissertation, interactive decision support is recommended as an alternative means of generating action plans to handle the unanticipated situations. In Section 2.4, research in decision support is reviewed in order to develop the basis for such a recommendation.

Interruptible Transient Goal Management

Transient goal refers to the active or current lowest-level goal (or subgoal) that the robot is trying to achieve [Sahota 94]. Transient goals change with time: an active goal is accomplished and a new active goal is put in place to be accomplished. Transient goal management is the process by which a robot evaluates and selects an appropriate transient goal to pursue. The intelligence of a robot's behaviour depends heavily on its transient goal management approach. If the transient goal is evaluated infrequently, the robot may continue to pursue a transient goal that is no longer appropriate with respect to the prevailing conditions in the environment. Transient goal management used in non-reactive planning robots like Shakey allows for evaluation of transient goals only when the entire plan completes or when the plan fails. Such management approach is found to be

inadequate for a dynamic environment.

Interruptible transient goal management is an approach where transient goals can be evaluated on demand. If the conditions in the environment dictate the need for a change in the transient goal, the existing transient goal is interrupted and replaced with a new goal. Such interruptability enables the robot to respond promptly to changes in the environment. In a dynamic world where multiple agents interact, where actions are continuous, and where the effects of actions are difficult to predict precisely, interruptible transient goal management is necessary.

In a strategic management setting, the concept of interruptible transient goal management is particularly important. If changes occur in the environment, an organization must promptly evaluate the relevancy of all selected strategic alternatives, including the ones that are currently being implemented and the ones to be implemented. Alternatives that are no longer relevant need to be cancelled and replaced. The decision process is not simple as it involves considerations of replacement alternatives, changes to the irrelevant alternatives to make them relevant, etc. The ability to promptly evaluate all available alternatives and their impact to the overall resource utilization is important. The urgency of the changes and the need for prompt responses pose a critical challenge to management. In the proposed responsive strategic plan, interruptible transient goal management is accomplished through interactive decision support which is discussed in more detail in Section 2.4.

Partitioned Architecture

Partitioned architecture is an approach proposed by Sahota to increase the efficiency of the robot's environment monitoring process [Sahota 93]. The approach breaks the responsibility of environment monitoring down into the detection of the control signal by the robot sensor and the analysis of the critical nature of the changes relayed by the control signal. Since the detection activity is less complex than the analysis activity, breaking down the activities allows the robot to promptly scan the environment and only initiate detailed analysis of the complex situations when changes are detected. The frequency of the scanning is therefore not compromised by the time required for detailed analysis.

In an organization environment, this partitioned architecture concept is very important. While monitoring a set of indicators may alert an organization to changes in the environment, the critical level of the changes requires a more detailed analysis. This analysis may require access to other internal and/or external information sources. The unstructured strategic management decisions may also require subjective analysis of the changes by senior management. In other words, interactive decision support is required to support some of the analysis activities. The breakdown of the detection and analysis activities allows the organization to employ different types of support to match the nature of the activity.

2.3 Environmental Monitoring and Executive Information Systems

Environmental monitoring has been practised by many large organizations. Ford Motor Co., Westinghouse Electric, Rockwell International, Celanese, Union Carbide, Kraft, J.C. Penny, Digital Equipment Corporation and Wang Laboratories are some of the American Corporations known to have environment monitoring groups to collect business intelligence [Fortune 84]. These groups consist of experts and senior managers with a variety of backgrounds. They perform continuous monitoring and evaluation of indicators identified as critical to the organization. Information collected are consolidated in order to piece together patterns that suggest an early warning of threats or opportunities. However, the process has largely been informal and unsupported by information technology [Elofson & Konsynski 91].

On the other hand, executive information systems (EIS) have been used by organizations as a common management tool to assemble large amounts of internal and external information and to assist with the decision making process. They represent a reasonable framework upon which support for environmental monitoring can be built. In this section, the EIS development is briefly reviewed to provide some insights into why EIS have not been able to adequately support environment monitoring.

IT has been used in organizations for several decades to automate highly routine and structured tasks found in operational areas such as accounting, finance, and sales. These

transaction processing systems were originally designed with little consideration for management's information requirements. In response to management's request for information, reports containing heavily aggregated data were generated as design after-thoughts [Watson et al 91]. Such a "by-product" approach to management information [Rockart 82] was not only wasteful but has been identified as largely responsible for "paralysis-by-analysis" (being bogged down by analysis without reaching any conclusions or recommendations), performance lag, frustration, and low organizational morale [Trippi & Salameh 89]. Many of these management information systems (MIS) still exist today and they make up a large percentage of the "legacy systems" in an organization. In recent years, business executives and IT professionals have recognized the need for special information systems designed to meet the information requirements of the senior management. Such systems, commonly called executive information systems (EISs), have the following characteristics [Zmud 86, Watson et al 91, Sanders 92]:

- capable of accessing and integrating a broad range of internal and external data across multiple hardware platforms;
- capable of extracting, filtering, compressing, and tracking critical data;
- capable of presenting information in graphical, tabular, and/or textual form; and
- easy to learn and use by executives.

Conceptually, an EIS consists of a set of software tools for accessing a network of multimedia information. This network encompasses internal and external data sources. Senior management use the tools to navigate the network and retrieve the available

information in order to explore the organization issues. EISs implementations have generated significant interest among senior management and these systems have been touted as the fastest growing business application in the Nineties [Maglitta 93, Gillan & McPherson 92, Kindel 93]. Unfortunately, studies show that most senior management have found their EIS experience unsatisfactory [Glover et al 92, Watson et al 91, Chen 95a]. In particular, several researchers point out that these EISs do not adequately support management's need to respond to rapid changes in the organization environment [Fedorowicz & Konsynski 92, Bourgeois & Eisenhardt 88, Trippi & Salameh 89].

A key factor in this inadequacy lies in the choice of information structures supporting the EIS. The information structures used in early EIS were usually organized as hierarchical structures according to business functional areas (eg. accounting, human resources, and marketing) or according to managerial activities (eg. communications, control, and organizing). They represent collections of the organization's information which are accessible through the implemented information systems. However, they lack the business or organization-wide perspective to information which is crucial to the decision making process of senior management. Recent EIS research efforts suggest alternative structures that incorporate organization entities such as goals and objectives to facilitate a business perspective to the EIS [Fedorowicz & Konsynski 92, Lee & Leifer 92, Chen et al 89, Sanders 92, Thierauf 91, Volonino & Watson 91]. These information structures are referred to as explicit representations of the organizations' mental models [Chen 93].

An individual's mental model has been defined as a map that consists of an "interconnected set of understandings, formed by frequently implicit views of what one's interests and concerns are, what is important, and what demands action and what does not" [Rockart & DeLong 88]. In other words, a mental model captures an individual's view of the important entities in his world and the relationships among them. Consequently, an organization's mental model is a shared view of the important entities in the organization environment, composed through the joint effort of the people in an organization.

The advantages of explicitly expressing an organization's mental model have been suggested to include increased organizational learning [Hedberg 81], increased autonomy [Churchman et al 57], preserved organization memory [Carley 92], integration of organization actors, and lower transaction costs [Walsh & Ungson 91]. Mental models are considered indispensable to information processing because they organize knowledge in simple, robust and parsimonious ways [Walsh 88]. Chen's work on an integrated organization and information systems (IOIS) model is an example of an IT instantiated mental model of the organization [Chen & Nunamaker 89, Chen et al 89, Chen et al 91, Chen 92, Chen 95a]. The IOIS model links business entities such as goals and objectives with IS entities such as systems, programs, reports and data elements. The model has been used to support a Repository-based EIS (R-EIS) [Chen 95a]. The organization-wide and business perspective of the model provides a contextual basis for senior management to better understand the information they receive as they navigate through the organization's

databases.

There is, however, another factor preventing current EIS from adequately meeting the needs of senior management. This factor relates to a general mis-understanding of how an EIS is being used by senior management to obtain the environmental information necessary to support their decision making. Environmental perception (the process of obtaining environmental information) falls into two categories: environmental scanning and focused search [Vandenbosch 94]. ***Scanning*** occurs when people browse through information without a specific problem to solve or a question to answer [Aguilar 67]. ***Focused search***, on the other hand, occurs when people are looking for specific information [Huber 91]. Some researchers advocate that scanning is crucial to the improved performance of executives, making them more knowledgable and resourceful [El Sawy 85, Thomas & McDaniel 90, Miller 93]. Focused search is believed to over-abstract and simplify the world and limit intuitive behaviour. Existing EISs (like the R-EIS proposed by Chen) are often designed to support environmental scanning, with senior management envisioned as using the EIS to browse through the organization's databases and external data sources.

Vandenbosch, however, discovered contradicting evidence from her empirical study of senior management's use of the EISs [Vandenbosch 94]. She found that an EIS was used more often for focused search of specific information, and environmental scanning was only observed in conjunction with focused search. If an EIS can be used for focused

search, senior management will be more inclined to use them for scanning as well. Vandenbosch's finding is not surprising in light of Mintzberg's observation that senior management often have to deal with large volume of decision making in a limited timeframe [Mintzberg 73]. Their activities are often fragmented, varied and issue-based. They rely on a network of contacts as their sources of information, and the information they seek are often characterized by its condensed nature. It therefore appears that even though scanning is important to the executives' performance upport for focused search of specific information is a more critical requirement of an EIS.

This does not mean that environmental scanning should not be supported by an EIS. In fact, both focused monitoring (ie. the automated support of focused search of specific information) and environmental scanning should be supported. There are several reasons for this dual emphasis. First, the potential improvement in executive performance resulting from environmental scanning [Miller 93] should not be ignored. Focused monitoring is intended to ease the effort on focused search of specific information in order that senior management can spend more time on environment scanning. Second, senior management needs to complement focused monitoring with environmental scanning in order to ensure that the closely monitored set of information does not introduce un-intended bias or "blind-spots" in the organization's view of the environment. The comprehensiveness of this set of information must be validated periodically. Third, by definition, an organization mental model contains information of interest to the organization. Therefore, the set of information that needs to be monitored is theoretically a subset of the information

contained in the EIS. In practice, this is not always true. The organization mental model evolves over time. The process of identifying the support for focused monitoring can help in fine tuning the EIS. This concept is supported by cognitive research findings. Cognitive theorists believe that a mental model determines how environmental stimuli will be interpreted, incorporated or synthesized, and whether or not cues will be noticed and used [Rumelhart 80]. Stimuli, in turn, help to enforce (maintain) or change (build) mental models [Collins & Gentner 87]. The dual emphasis of environmental scanning and focused monitoring works in a complementary manner to fine tune the information requirements of an EIS.

The incorporation of a focused monitoring support in an EIS is, however, not trivial. The support to the 'passive' mode of information capture in environmental scanning needs to be supplemented by support for 'active' information capture. In essence, environmental scanning makes use of whatever information is available in the system but focused monitoring identifies and requests specific information to be made available for its use. For example, mechanisms must be available to automatically capture the requested information, to analyze the information in order to filter out the critical situations from the non-critical ones and alert management appropriately. If the organization is knowledgeable about these situations, software can be developed to automate the information capture and analysis tasks. In a complex organization environment, some of the situations may not be well-defined enough to support automation of the analysis tasks. Furthermore, some of the requested information may not exist in a format that can be

automatically captured. In such situations, software must be available to interface with the organization's environment monitoring group to allow manual entry and analysis of the requested information. Regardless of the mechanism by which the information is captured, there is a need for scheduling and coordinating the execution of these information capturing applications. This automated support for information capture is the basis of the difference between the passive and active support required for the environmental scanning and focused monitoring.

The IT support to focused monitoring is further complicated by the fact that the set of information that needs to be monitored is constantly changing. Recalling the discussion of the reactive planning concepts in Section 2.2, focused monitoring is basically the implementation of the planned perception concept in the organization environment and the set of information to be monitored is the perception plan of the organization. According to de Compos and Monteiro de Macedo, the perception plan must also be monitored and updated to reflect the conditions in the environment. To manage this evolving perception plan, a mechanism is needed to allow an organization to dynamically link the monitoring requirements with the information capturing and analysis applications and to schedule the execution of these application. Chen proposes the linking of information reporting applications through the IOIS model as a means of building and delivering an evolving EIS [Chen et al 91]. However, the focus of Chen's discussion was primarily on the support of environmental scanning. The Responsive Corporate Information Model (RCIM) proposed in this thesis extends the concepts in the IOIS model

to provide a more 'active' support to focused monitoring. The IOIS Model and Chen's work on executive information systems is summarized in Section 2.5.

2.4 Supporting Strategic Decision Making in a Dynamic Environment

The adaptation of the reactive reasoning and planning concepts to support the strategic management process is motivated by the similarities between the dynamic environments in which the organization and the robot operate. The adaptation provides a conceptual basis for the responsive strategic plan. However, the differences in the two environments necessitate the fine tuning of this conceptual basis. For example, current management technology is unable to support automation of the strategic planning process as a rule-based system. Alternative means to a hybrid planning system (like the one used by the Theo-Agent System) must be employed within the RCIM to alert management to the unavailability of pre-defined plans for the impending situations. A review of related research in decision support resulted in the following concepts being added to the design of the RCIM; namely, the interactive decision support approach, the flexible architecture of the RCIS (the RCIM prototype system), the need for decision logging, the integration of the RCIS into the organization's EIS framework, and the development of the RCIM meta-model. These concepts are discussed in this sub-section.

Interactive Decision Support

Interactive decision support has been adopted as the primary mode of decision support within RCIM. The approach incorporates the human decision maker into the operation of a DSS. Instead of completely automating the decision making process, the DSS interacts with the decision maker, influencing and guiding the decision making, but relying on the decision maker for the primary judgement [Keen 86]. The application of interactive decision support originated from a review of the design goals and principles of decision support system.

Decision support systems (DSSs) were introduced in the 1970s as a new approach of combining information systems with analytic tools [Gorry & Scott Morton 89]. It proposes the meshing of human judgement and computer technology in ways that can improve the effectiveness of decision makers, without intruding on their autonomy. Presented as an alternative to batch processing and centralized operations, this computing paradigm promotes the use of flexible, interactive tools to assist in non-routine planning and decision making. However, it is important to recognize that the goal of a DSS is to help people make better decision, not to replace them [Larichev and Petrovsky 88]. In other words, it is logical to incorporate the decision makers as a component of the DSS operation.

In fact, research indicates that interactive decision support is most appropriate for

unstructured decisions. Gorry and Scott Morton categorize decisions into structured and unstructured decisions. Structured decisions are repetitive and routine in nature, and definite procedures exist for handling them [Gorry & Scott Morton 89]. In contrast, unstructured decisions deal with problems that occur infrequently, where few or no decision rules are available to assist management in making these decisions. Structured decisions lend themselves to complete automation. Early DSS research and implementation efforts have largely focused on such automation, resulting in the development of complicated mathematical models for analyzing volumes of data. However, these techno-rational approach to problem-solving and decision-making are too inflexible for the unstructured decisions [Angehrn & Jelassi 94, Larichev & Petrovsky 88].

Gorry and Scott Morton argue that the focus of IT support for the unstructured decisions should be on the explicit modelling of these decisions, with the human decision maker providing the judgement and evaluation as well as insights into the problem definition [Gorry & Scott Morton 89]. The modelling process encourages the decision makers to examine the organization entities related to the decisions, together with the complex relationships among them. It is in the process of interacting with the DSS that improved problem understanding and new decision alternatives arise, resulting in improved decision making. Furthermore, modelling also leads to improved understanding of the decision making process and eventually to its automation.

Mintzberg et al comment that "strategic decision process is characterized by novelty, complexity, and open-endedness, by the fact that organization usually begins with little understanding of the decision situation it faces or the route to its solution, and only a vague idea of what that solution might be and how it will be evaluated when it is developed." [Mintzberg et al 76]. In other words, strategic management decisions are typically unstructured decisions. It therefore follows that interactive decision support is an appropriate approach to adopt within the proposed IT support for the strategic management process.

An example is used to illustrate how the interactive decision support is applied in supporting the concept of interruptible transient goal management. First, the system alerts the senior management to critical changes in the environment. Second, all strategic alternatives that are impacted are identified by the system so that the senior management can examine the impact closely. Third, the system prompts the senior management to develop new alternatives or changes to existing alternatives. Fourth, the system enables the senior management to select a new set of strategic alternatives for implementation. In essence, the system guides and influences the decision making process, although the senior management retains the responsibility for decision making.

Flexible Architecture of the RCIS

The unstructured nature of the strategic management decision poses some initial concerns

in formulating the architectural structure of the RCIS, the prototype system supporting the RCIM. The dominant model of human decision making is the "intelligence-design-choice" model proposed by Simon [Simon 60]. The model depicts a three-phased process: an intelligence phase where a problem is identified and information regarding the problem and solution is collected; a design phase where alternatives for solving the problem are specified and evaluated; and a choice phase where one of the alternatives is selected for implementation. This model has been used by many DSS researchers as a conceptual basis for explaining the process of decision making and for developing the first generation of DSS.

However, after studying 233 decision processes, Witte found that none of the processes exhibit the three distinct sequential phases [Witte 72]. Mintzberg et al also describe the strategic decision process to be a recursive, discontinuous process, involving many difficult steps and a host of dynamic factors over a considerable period of time [Mintzberg et al 76]. This recursive, discontinuous view of the unstructured decision process appears to contradict the "intelligence-design-choice" model. However, using a general model of the strategic decision process, Mintzberg's group was able to represent 25 unstructured strategic decision processes as different path configurations through the three distinct phases. Therefore they concluded that instead of three sequential phases, the basic structure of the strategic management process consists of multiple iterations of the intelligence, design and choice steps, while the movement from one step to the other follows no fixed pattern.

Mintzberg et al's study provides two important insights on the architecture of a DSS designed to support the strategic management process. First, the DSS must address the support of the intelligence, design and choice steps separately. Second, the design must allow the decision maker to move from one step to another, depending on the nature of the decision or on the individual's practice. These considerations are incorporated into the architectural design of the prototype system designed to support the RCIM.

The Need for Decision Logging

Nunamaker et al characterize an intelligent organization as one that is learning-focused [Nunamaker et al 89]. Learning is not a by-product of a DSS but a valuable and primary contribution [Keen & Scott Morton 78]. However, in practice, few DSS have adopted models of learning processes as a basis for eliciting the components and the dynamics of a DSS [Angehrn & Jelassi 94].

Literature review indicates that DSS can support organization learning in three different ways. First, DSS allows an organization to learn from past decisions. Argyris and Schon note that for organizational learning to occur, the learning agents' discoveries, inventions, and evaluations must be embedded in the organizational memory [Argyris & Schon 78]. Stata suggests that organization learning occurs through shared insights, plus knowledge and mental models built upon the retention of past knowledge and experience [Stata 89]. Learning organizations use this historical information to guide their behaviour [Levitt &

March 88].

Second, DSS allows an organization to learn more about the decisions on hand. Organization learning takes place as members of the organization question underlying assumptions, procedures, and values, and attempt to substitute new paradigms for old ones [March 91]. In other words, the explicit modelling of the decisions not only help individual decision makers to improve his understanding of the problems and the solutions (thus improving the individual's decision), it can also facilitate the critique of the decision by other members of the organization. This joint evaluation of the decisions is crucial to organization learning.

Third, DSS allows an organization to learn to deal with changes to decision. An intelligent organization is technology-competent and information-literate [Nunamaker et al 89]. Such an organization knows what information is needed, what information systems are available and how the available technology can be exploited. Organization crises frequently occur because of a lack of information about the issues and an inability to assess what is already known and/or locate information that is available. In a crisis situation, an individual's ability to think, to explore new alternatives, to analyze and interpret information, to decide and to act are affected. Decision maker becomes short-sighted and unable to predict consequences of alternative courses of action. By explicitly modelling the strategic management issues, a DSS can present a set of related information to assist the decision maker in dealing with the impending crises.

This review points out the significance of explicitly modelling the strategic decisions in a DSS and retaining the information about the decisions to assist in both current and future decision making. A decision log is therefore incorporated in the design of the RCIM.

Integration of the RCIS into the EIS Framework

Bourgeois and Eisenhardt examine several cases of decision making in a dynamic environment and suggest the following differences between the successful and unsuccessful decisions in such environment [Bourgeois & Eisenhardt 88]. First, successful decision makers track information in real time to obtain an up-to-date picture of the organization environment. Operating data like cashflow and inventory are used effectively in the decision making process. Unsuccessful decision makers use historical data for projection and analysis but fail to capture or make use of up-to-date information about the environment. Second, a successful organization immediately starts to develop multiple alternatives when it is faced with a major decision. Several alternatives are tried out in order to learn more about the problem. An organization that develops a single solution and only seeks to develop alternative when the first solution fails is slow in responding to the demand of the dynamic environment. In a dynamic environment, a slow response can be as ineffective as a wrong decision. Third, a successful organization solicits input from a lot of people during the decision process and tries to obtain consensus. If consensus cannot be reached, a choice is made by top management and the organization

moves forward. Waiting for the consensus slows the response down. Instead, the organization implements its 'best' alternative, monitors the effects and makes necessary changes to its plans as it moves forward. Unsuccessful organizations wait for consensus and in the process loses valuable time. Fourth, successful choices must be well integrated with other decisions and with the overall strategic direction of the organization. Less successful choices are often selected in isolation from other decisions.

These empirical findings confirm the conceptual basis of the responsive strategic plan, namely, the significance of the development and tracking of multiple alternatives, the evaluation of all alternatives with respect to the overall goals of the organization, the selection of the 'best' alternatives to allow the organization to move forward, and the 'cautious' commitment to the selected alternatives. At the same time, the findings point to the importance of using real time operational data to support decision making. Historical data, while useful for trend analysis and projection, are not timely enough to deal with the rapidly changing situations. The use of operational data in a DSS has also been suggested by other researchers. Keen suggests that an organization-wide DSS should access all organizational data resources, including the transaction processing system, in order to use the operational data directly [Keen 86]. Angehrn & Jelassi suggest integrating the DSS with an organization's EIS, to provide the DSS with a broader information collection systems, while taking advantage of EIS research on executive information use [Angehrn & Jelassi 94]. Therefore, Bourgeois and Eisenhardt's empirical study provides additional support to the integration of the RCIS with the organization's EIS framework.

Development of the RCIM Meta-Model

Researchers generally agree that customizability is an important design concept for a DSS. Specifically, a DSS must model the manager's use of knowledge and information [Ciborra 88]. An organization's acceptance of a DSS depends heavily on how well the system can be adapted to model the terminology and practice of the organization [Chen 88]. Successful IT support reflects management practice and philosophy [Marx 91]. DSS must facilitate instead of constrain the development of a business strategy [Ward et al 90]. The conceptual design of the RCIM is based on a meta-modelling approach. The approach provides for the customization of the RCIM model to an organization. This meta-modelling concept is also used in Chen's IOIS Model [Chen 88] and is discussed in more detail in Section 2.5.

2.5 Integrated Organization and Information Systems Modelling

The integration of organization models and information systems models to facilitate a business perspective in information systems planning and development has been actively pursued by researchers and practitioners [Law 88, Martin 87, Pohl & Jarke 92, Oivo & Basili 92, Yu 93]. Organization models are high-level conceptual constructs for modelling an organization's business and management processes and activities. These constructs include organization structures and goals, business processes and strategies, strategic

assumptions, critical success factors (CSF) and their relationships. Information models, on the other hand, include constructs such as business application systems, programs, reports, data sets etc. An integrated model aligns an organization's information systems to its goals and strategies, enabling the organization to co-ordinate its systems development and support activities to meet the organization's business objectives. Many organizations have invested significant resources to build these integrated information models (often referred to as enterprise models). Unfortunately, these models have primarily been used to support the information resource management and information systems planning and development life cycle. Because of the limited usage, an adequate return-on-investment has not been achieved from these models.

Chen proposes the use of these integrated organization and information systems model to support the building and delivery of business application systems [Chen et al 89]. The concept allows the end users to directly access the integrated model as part of a business application. Since the integrated model contains up-to-date information about the organization's information resources, the direct access enables the end users to make use of all information resources in the organization within their application. Chen illustrates the concept with an example that uses the IOIS model to support a Contextual Information System (CIS) [Chen et al 91]. The CIS is an EIS designed to provide the end users with contextual information to understand the reports generated by the organization's application systems. Figure 2-1, adopted from [Chen et al 89], is a simple IOIS model defined for an organization that uses the critical success factor approach to strategic

planning.

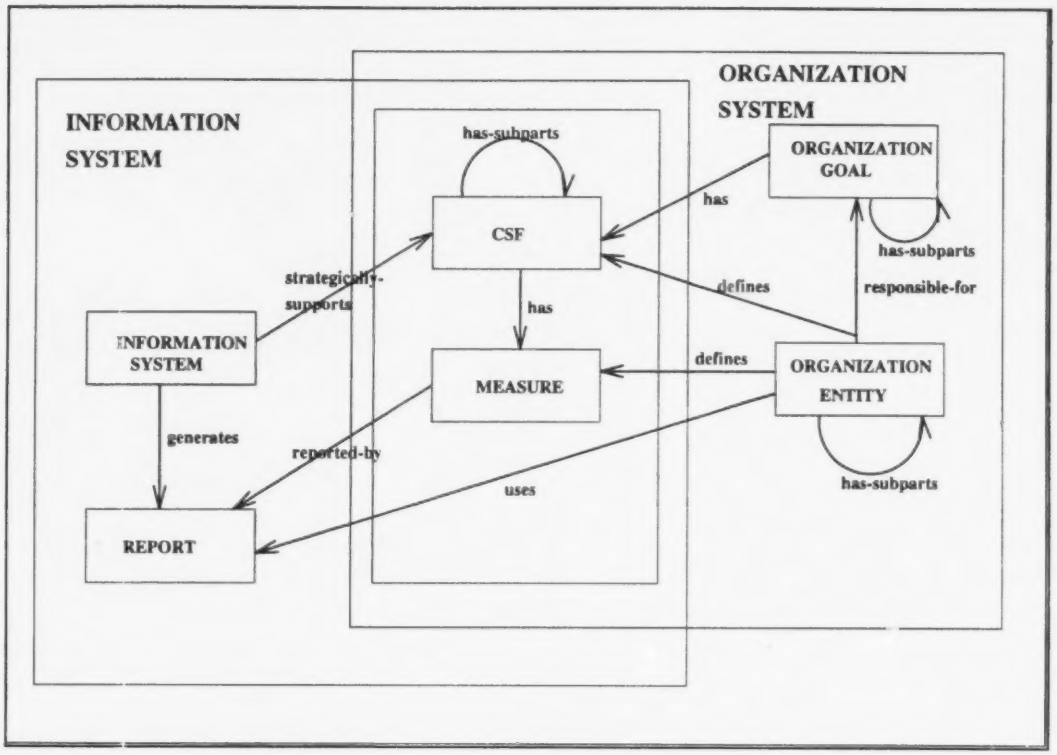

Figure 2-1 A simple IOIS Model of the extended CSF Method

The model consists of the Object Types *ORGANIZATION-GOAL, CSF, MEASURE, INFORMATION-SYSTEM* and *REPORT*. Relationship Types are defined between two or more Object Types. For example, a binary Relationship Type, *ORGANIZATION-GOAL-has-CSF* is defined to express the relationship between instances of the two Object Types, *ORGANIZATION-GOAL* and *CSF*. Using this IOIS model, the user can model the various organization and information entities such as **Goal1**, **CSF1**, and **Annual-Sales** shown in Figure 2-2, which are instances of *ORGANIZATION-GOAL, CSF*, and *REPORT* Object Types respectively.

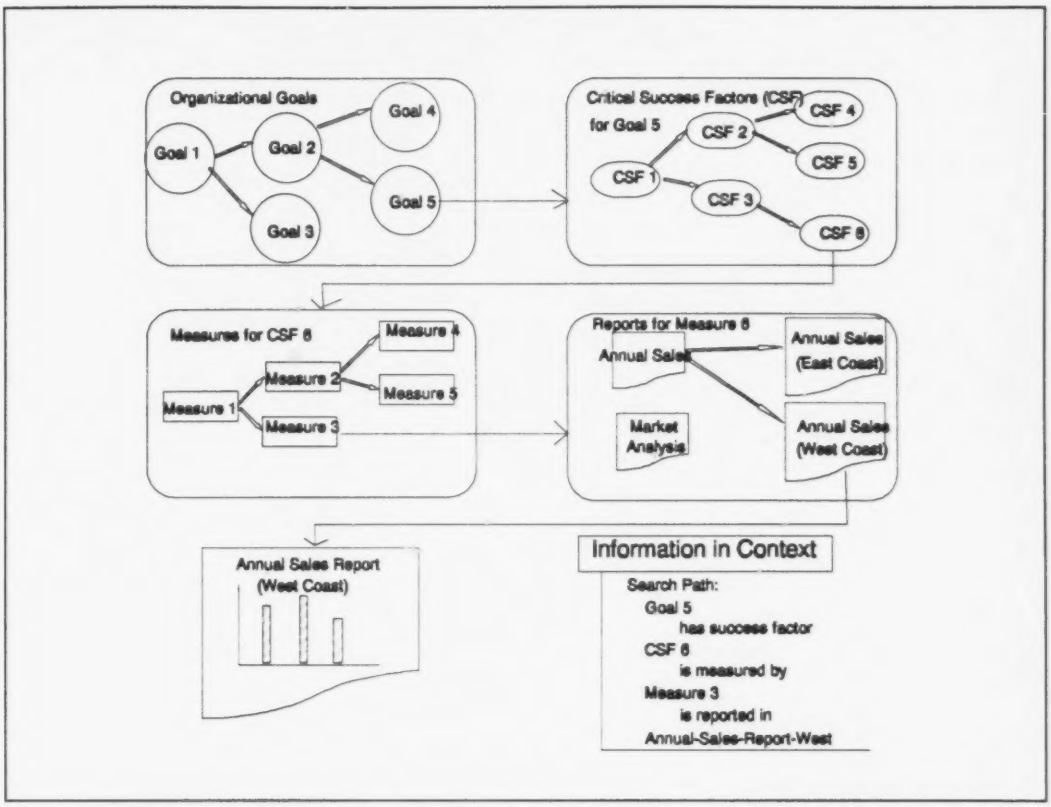

Figure 2-2 A Scenario of navigating through an IOIS Model in a CIS

Figure 2-2 illustrates graphically the operation of the Contextual Information System. In the example, a manager starts navigating through the system by examining all instances of the IOIS Object Types *ORGANIZATION-GOAL*. The manager follows the relationship *ORGANIZATION-GOAL-**has**-CSF* shown in Figure 2-1, to look at all CSFs related to the *ORGANIZATION-GOAL* instance, **Goal5**. The manager then looks at all instances of the Object Type *MEASURE* for **CSF6** by following the relationship *CSF-**has**-MEASURE*. After choosing **Measure3**, he follows the *MEASURE-**is-Reported-by**-REPORT* relationship to select the **Annual-Sales(West Coast)** report. Selection of the report triggers the execution of the reporting program to generate the report and display it on the screen.

Throughout the operation, the search path is recorded by the system and can be displayed to provide contextual information to the user. In this way, the IOIS Model provides the user with the background information (i.e., context) to understand the report generated by the system.

Customizability of the IOIS Model

A meta-modelling approach is used by Chen to support IOIS modelling. Meta-modelling concept has been commonly used in meta-CASE systems such as MetaView [Sorenson et al 88] and the Information Resource Dictionary System (IRDS) [Law 88]. The approach supports the abstraction of a model's structure in its meta model. The meta model can then be extended to generate a customized model for the user. Tools, developed on the basis of the generic model defined in the meta model, can be used to generate and use the customized model.

The ability to customize an integrated organization and information systems model to an organization's culture and management practices is crucial to the organization's acceptance of the model [Chen 95a]. The meta-model used by Chen is briefly described here to provide a basic understanding of the concept. Details of Chen's meta-model are available in [Chen 88, Chen et al 89]. Figure 2-3, adapted from [Chen 88], uses the extended ERA diagramming technique to describe the three levels of the IOIS Model. The ERA technique, originally used for conceptual data base design [Chen 76, Teory et al 86], is

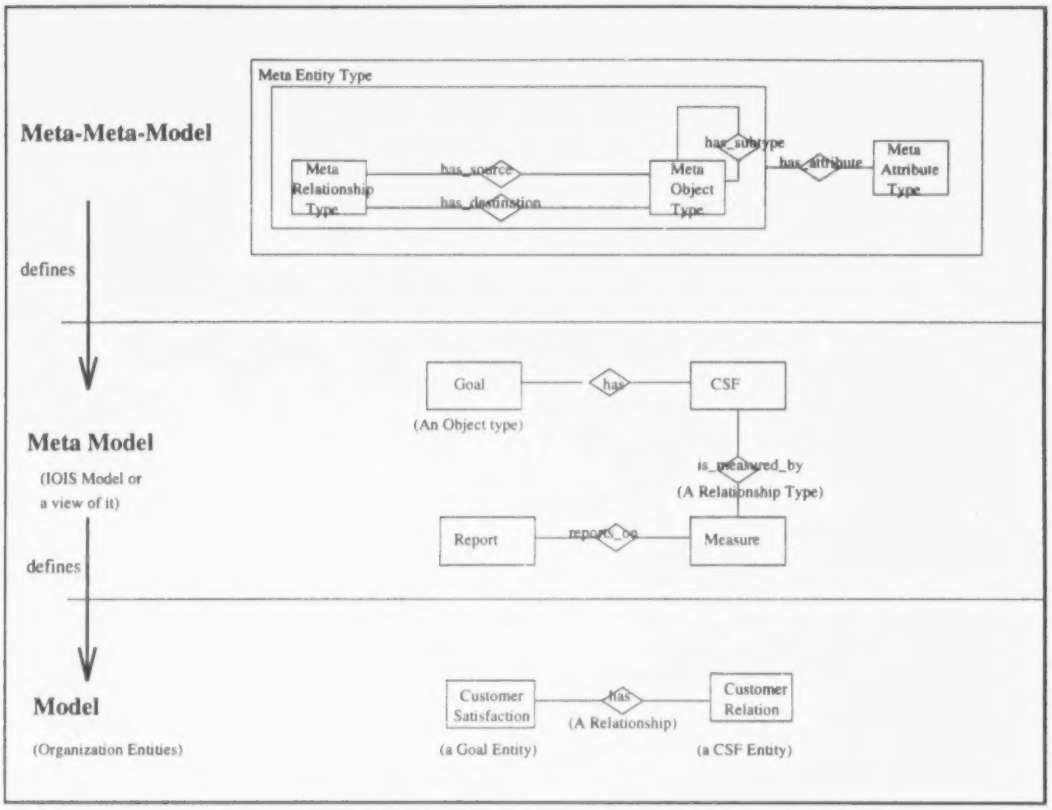

Figure 2-3 The Three Meta Modelling Levels of the IOIS Model

also used in MetaView [Sorenson et al 88] and the IRDS [Law 88].

The first level in the scheme, representing the highest level of abstraction, is the meta-meta model. It defines the meta model (the IOIS Model), in the second level of the scheme. The meta-meta model consists of four subtypes, a **Meta Entity Type** and three of its subtypes: **Meta Object Type**, **Meta Relationship Type**, and **Meta Attribute Type**. **Meta Object Type** can be used to model concepts, entities, events, things etc in a domain. **Meta Relationship Type** specifies the structural relationships among objects of certain **Meta Object Types**. **Meta Attribute Type** is used to represent the generic

characteristics of both the **Meta Object Type** and the **Meta Relationship Type**. Constraints and operations can then be added within the meta-meta model to augment the expressiveness of the model [Chen & Nunamaker 89]. For example, each **Meta Object Type** and **Meta Relationship Type** is made up of a name, a comment, and a set of **Meta Attribute Types**. **Meta Attribute Types** can be used to express unstructured and procedural knowledge, as well as decision rules. A **Meta Relationship Type** is defined as an ordered list of two or more **Meta Object Types**. The definitions in the meta-meta model are then captured in a meta language, which will be used to guide the definition of the meta model for an organization.

Using this meta language, a user can customized an IOIS Model (the meta model) to an organization's culture and management practices. For example, the IOIS model shown in Figure 2-1 is customized for an organization that uses the critical success factor approach to strategic planning. It consists of the Object Type *CSF* and the Relationship Type *ORGANIZATION-GOAL-**has**-CSF*. Constraints can be defined so that each Relationship Type is automatically matched with a reversed Relationship Type for cross referencing the target system specification. In the given example, the reversed Relationship Type can be defined as *CSF-**are-important-to**-ORGANIZATION-GOAL*. This customization is based on the organization belief that a cross referencing capability can reduce user effort in defining a system and facilitate the user's understanding of the target system specification.

At the third level, the users make use of the definitions in the IOIS model (the meta

model) to describe the various organization and information entities. The IOIS Model determines what can be modelled and controlled in the third level, the IOIS instance level. Multiple views can be defined to represent specific aspects of the meta-model to support different applications; each view being a subset of the meta model. For example, in Figure 2-3, the Objects **Customer-satisfaction** and **Customer-relation** are described as instances of Object Types *ORGANIZATION-GOAL* and *CSF*, and the relationship between the objects is described as an instance of the Relationship Type *ORGANIZATION-GOAL-**has**-CSF*.

Chen's research on the IOIS model provides a foundation for implementing the RCIM. The latter can be considered as a specialized IOIS to support a responsive strategic management process. The key in this specialization is the inclusion of an 'active' support in the model.

Chen's IOIS model provides a 'passive' mode of accessing the organization's information. Navigating through the model, the end users can select and invoke a procedure manually to get a desired report. This mode of access is quite acceptable for an EIS supporting environmental scanning. However, to support focused monitoring, a more 'active' support is required. First, the IOIS model must be extended to incorporate the knowledge to identify the specific conditions to which senior management must be alerted. Second, instead of incorporating procedures for accessing the target IS in the IOIS Model and allowing users to invoke the procedures to get the required reports and information, a

more active support can be achieved if software agents are incorporated in the model. These software agents are responsible for scanning the environment, recognizing the specified conditions, and directing the information to the appropriate parts of the information model to assist in decision making. In essence, the software agents perform similar functions as the sensors in the reactive robotic control systems, making use of the information model as the perception plan. The 'active' support provided by the RCIM enables the system to promptly identify the impending critical situations in the environment. The conceptual design of the RCIM is described in Chapter 3. Details of the design and operation of the 'active' support is covered in Section 3.1 and Chapter 5 respectively.

2.6 Business Process Re-engineering within the Context of Responsive Strategic Management

Business process re-engineering (BPR) has been looked upon by many organizations as a means to gain competitive advantage in the 1990s. The usual approaches for boosting performance - process rationalization and automation - have been criticized as just mechanization of the old ways of doing business [Hammer 90]. They leave the existing processes intact and simply use technology to speed up the processes. These conservative approaches fail to produce the dramatic improvements required by the organizations because they do not address the fundamental performance deficiencies of the processes.

In contrast, BPR advocates the development and implementation of a set of radical, revolutionary ideas in order to dramatically improve performance.

Successful re-engineering experiences reported by organizations such as Ford Motor Company, Mutual Benefits Insurance Life and Rank Xerox U. K. [Hammer 90, Davenport & Short 90] grasp the attention of the business community and many organizations eagerly adopt the re-engineering concepts in their quest of becoming more competitive. However, despite the initial excitement, it is estimated that over 50% of the BPR projects have failed [Revenaugh 94]. While there may be a variety of reasons for the failure of the projects, it is believed that some of the projects failed because the organizations under-estimated the difficulties associated with the implementation of the new processes.

In the remainder of this section, the BPR concept is discussed within the context of the responsive strategic management process. The discussion illustrates how the responsive corporate information model can support a BPR project through its tumultuous implementation phase.

Business Process Re-engineering

Business process re-engineering is touted as an approach for achieving dramatic improvements in an organization's performance within a relatively short period of time. BPR focuses on examining the work flows and processes within and between

organizations. A business process is a set of logically related tasks performed to achieve a definite business outcome [Davenport & Short 90]. By modelling the processes and critically examining "why" each particular process activity is undertaken, an organization re-engineers its processes to achieve dramatic improvements in cost, time, responsiveness, performance quality, etc.

The BPR concept is formed on the basis that most processes operating in today's organization originate from an outdated set of assumptions about the available workforce and technology [Hammer 90, Dennis et al 94]. Most of these business processes were designed in the post-war era to operate in an environment typified by an unskilled workforce and the inability of technology to integrate information across organization boundaries. The prevalent management focus was on cost, growth and control. While these processes have been incrementally changed over the years as technology advances, little attempt has been made to challenge the original assumptions and the design of the processes. The current skilled workforce and advance in information technology offer the opportunities to expand the management focus to include quality, innovation and service. However, organizations must be innovative to explore the available opportunities and use modern management approaches and information technology to redesign business processes that fit current and future environment.

Hammer identifies seven principles to guide an organization through a BPR project [Hammer 90]:

1. Organize about outcomes, not tasks.
2. Have those who use the output of the process perform the process.
3. Subsume information processing work into the real work that produces the information.
4. Treat geographically dispersed resources as though they were centralized.
5. Link parallel activities instead of integrating their results.
6. Put the decision point where the work is performed, and build control into the process.
7. Capture information once and at the source.

Davenport and Short also identify re-engineering principles, but more importantly, they provide a methodology for the re-engineering effort [Davenport & Short 90]. The methodology involves five phases:

1. Developing business vision and process objectives.
2. Identifying processes to be redesigned.
3. Understanding and measuring existing processes.
4. Identifying IT levers.
5. Building a prototype of the redesigned processes.

Hammer and Champy identify nine kinds of changes that occur when an organization re-engineers its business processes [Hammer & Champy 93]. These changes include work unit changes, job changes, people's role changes, job preparation changes, focus of performance measures and compensation changes, advancement criteria changes, values changes, organization structure changes and executive changes. The magnitude and

diversity of these changes are significant. Moreover, while these changes may take place in different areas of the organization, they must be managed in an integrated way [Hammer 90].

Indeed, BPR advocates drastic changes to business processes in order to gain competitive advantages. Drastic changes carry a high degree of uncertainty. It therefore follows that management of these changes is critical for successful implementation. Innovative thinking and the modelling and analysis of existing processes may be important to the design of new business processes, but ultimately, the success of BPR depends on the ability of the organization to manage the changes that result directly or indirectly from the implementation of these new processes.

It is therefore interesting to note that Davenport and Short's methodology does not address the implementation phase at all. This omission also seems to be reflected in the design of BPR software tools. A research report comparing several commercially available BPR software tools reveals that none of these tools provide support for the implementation phase of a BPR project [Bradley et al 95]. The report describes four BPR tools including DECmodel from Digital Equipment Corporation [DEC 92], ProcessWise from ICL [ICL 93], Business Design Facility from Texas Instrument [TI 93] and Enterprise Modelling System from Interfacing Technologies [IT 94]. A methodology is proposed for assessing the strengths and weaknesses of BPR software tools and helping BPR practitioners to assess how a particular BPR software tool will fit in a particular process or industry

sector. The four BPR tools are compared using the methodology. All tools offer modelling and simulation capabilities to allow the performance of a process to be assessed, but they offer little support for process implementation. With a total of sixty features grouped under seven categories, the methodology does not include any feature that supports BPR implementation. This lack of emphasis and support to the BPR implementation phase can have serious implications.

It is important to recognize that BPR is a strategic management approach [Patching 94, Revenaugh 94]. It is an approach to assist an organization in defining and establishing new ways of achieving business goals. Because BPR emphasizes innovative thinking and introduces drastic changes to the organization's processes, a BPR project is, by nature, a strategic management process in a dynamic environment. As such, a BPR project must be managed as a responsive strategic management process.

Figure 2-4 aligns the three strategic management phases described in Section 2.1 with the phases supported by Davenport and Short's methodology, by the four BPR software tools, and by the responsive strategic management approach proposed in this thesis. The methodology described by Davenport and Short addresses only the goal setting and strategic planning phases. The exclusive focus on the first two phases reflect a traditional strategic management approach. Unfortunately, the idea of designing a complete set of new processes and then systematically implementing them to completion is difficult to achieve in a dynamic environment. The methodology is therefore incomplete.

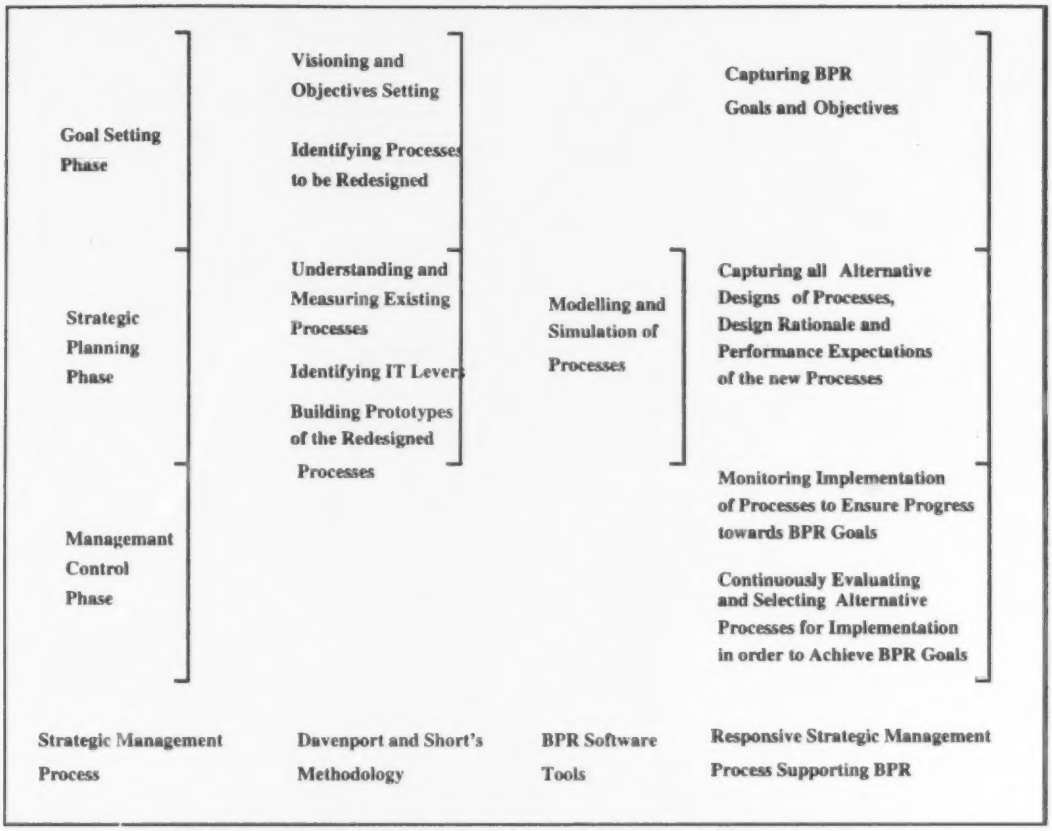
Goal Setting Phase
Strategic Planning Phase
Managemant Control Phase
Visioning and Objectives Setting
Identifying Processes to be Redesigned
Understanding and Measuring Existing Processes
Identifying IT Levers
Building Prototypes of the Redesigned Processes
Modelling and Simulation of Processes
Capturing BPR Goals and Objectives
Capturing all Alternative Designs of Processes, Design Rationale and Performance Expectations of the new Processes
Monitoring Implementation of Processes to Ensure Progress towards BPR Goals
Continuously Evaluating and Selecting Alternative Processes for Implementation in order to Achieve BPR Goals
Strategic Management Process
Davenport and Short's Methodology
BPR Software Tools
Responsive Strategic Management Process Supporting BPR

Figure 2-4 Comparison of the BPR Phases Supported

At the same time, the four BPR software tools only address the support for the strategic planning phase. Modelling and simulation allows the performance of a process to be assessed before decisions is made regarding the implementation of the process. However, it does not offer any support to deal with changes in the management control phase.

In contrast, the responsive strategic management approach uses the information captured during the goal setting and strategic planning phases to effect a "responsive" implementation of the BPR process. The captured information includes the alternative process designs, the design rationale (assumptions) and performance expectations of the

processes. The information allows the organization to monitor the performance of the implemented processes and adjust the process design and implementation to reflect the conditions in the environment. By recognizing the impact of changes and supporting the organization to manage the changes, the responsive strategic management approach provides a much needed support to the implementation phase of the BPR project.

2.7 Summary of Findings

In today's dynamic environment, it is very difficult for an organization to develop a comprehensive strategic plan and implement it to completion. Rapid changes in the environment threaten the viability of the goals and the relevancy of the plan. A responsive strategic management process allows an organization to use a comprehensive strategic planning approach to develop a responsive strategic plan that can withstand the effects of changes in the dynamic environment.

There are three key aspects to the responsive strategic management process.

1. It is important to include all strategic alternatives identified throughout the life cycle of the strategic management process as components of the responsive strategic plan.
2. It is important to emphasize the identification of the intermediate objectives (the "what-to-do's") versus the actions (the "how-to-do's") during the planning phase, and the deference of the final decision on the actions until the latest possible time to allow the

prevalent environmental conditions to be taken into considerations. The approach also encourages the organization to explore alternative means of achieving the intermediate objectives. This emphasis is very important since the responsiveness of the overall strategic plan depends on the number of alternatives in the overall plan.

3. The development and management of such a strategic plan requires IT support, a key component of which is the Responsive Corporate Information Model (RCIM).

The RCIM is an integrated organization and information model that utilizes an organization's information resources to support the strategic management process. The following design requirements are identified for the RCIM:

1. The RCIM must contain high-level conceptual constructs for modelling the components of a strategic plan. These includes the goals, objectives and action plans; and the complex relationships among them.

2. The RCIM must support the modelling of the assumptions behind the strategic alternatives and the indicators for measuring the performance and/or progress of these alternatives. The network of assumptions and indicators forms a perception plan for focused monitoring of the strategic management process. These perception plan must remain flexible and extensible.

3. The RCIM must support active linkage to the organization's information systems. These linkages allow the RCIM to make use of these systems to scan the environment, recognize the impending conditions and direct the information to the appropriate parts of the model to assist in decision making.

4. The RCIM must support the formulation of a selection algorithm that an organization can use to systematically select a set of strategic alternatives to accomplish its overall goals. Although the exact algorithm may vary with the organization and the circumstances, it is always goal based and resource based. In other words, the algorithm always seeks to maximize the accomplishment of the overall goals with efficient use of the resources such as financial and/or human resources. Therefore, modelling concepts must be available to handle the resource requirements for the strategic alternatives and provision must be available for incorporating customized selection algorithms into the system.

5. The RCIM must support the "what-if" evaluation of the strategic alternatives. The evaluation allows the organization to examine the proposed changes to the responsive strategic plan and explore additional alternatives or modification of existing alternatives.

6. Recognizing the nature of the unstructured decisions involved in the strategic management process, it is important for the RCIM to support senior management in manually selecting certain alternatives even when they are not explicitly selected by the selection algorithm. These selections may be based on management intuitions or on rationale that are confidential in nature. The provision of a "manual selection" capability reflects a real world requirement of a complex organization environment.

7. The RCIM must support the capturing of direct and indirect changes to the strategic plan. Direct changes occur when environmental changes result in assumptions being validated or invalidated. These changes will be immediately reflected in the status of the assumptions and in the viability of the associated strategic alternatives. Indirect changes

are changes that must be evaluated against some pre-determined criteria before their impact to the strategic plan can be assessed. For example, changes in the values of performance indicators need to be evaluated to determine if a critical level is reached where action must be taken to change the existing action plans or to replace them with alternatives. Both types of changes need to be supported.

8. Customizability of the RCIM to the organization culture and practice is crucial to its acceptance. Design concepts must be built in to support customizability in the formulation of the RCIM.

9. To support organization learning, a decision log is built into the RCIM design. This log provides the opportunity for an organization to study the rationale behind its strategic decisions and to analyze its decision making practice over time.

These requirements are captured in the design of the RCIM which is described in detail in Chapter 3.

Chapter 3

Responsive Corporate Information Model

The Responsive Corporate Information Model (RCIM) is a view of an organization-wide information model designed to support a responsive strategic management process. It consists of high level conceptual constructs to model the strategic plan entities such as goals, objectives and action plans, and their relationships to information systems entities such as application programs and data elements. The model enables an organization to utilize its information systems resources to assist in monitoring and responding to changes in the environment.

As has been pointed out in Section 2.5, the RCIM can be viewed as a specialized IOIS model. Therefore the same terminology used in describing the IOIS model [Chen 88, Chen 89] is used to describe the RCIM. In other words, the modelling constructs for modelling the strategic plan entities and information systems entities are referred to as Object Types and the constructs for modelling the relationships between the Object Types are referred to as Relationship Types.

The decision to use the object-oriented modelling approach for the design of the RCIM,

instead of other modelling approach such as a rule-based model, is multi-fold. Object-oriented approach has been recognized as a unified paradigm in the design and implementation of programming languages, knowledge base systems, database systems, and user interface design [Zaniolo et al 86]. Blanning extended the object-oriented approach into organization modelling and suggested that the approach can be applied to the analysis of organizations as well as the design and implementation of systems that support the organization [Blanning 87]. Chen further extended the approach into the IOIS model to integrate organization and information systems models [Chen 88]. The approach is also used in the IRDS project for organization and information systems modelling [Law 88]. The notion of object is found to reduce the semantic gap between the organization model and the real world [Chen 88]. The use of an object-oriented approach in the RCIM model therefore follows a strong research precedence.

The object-oriented modelling approach has also been well-received by the artificial intelligence (AI) researchers for knowledge representation. Frames are basically an application of object-oriented programming for AI and expert systems [Turban 93]. A frame is an object, and each slot in the frame is an attribute containing declarative knowledge or procedural knowledge about the object. The modelling flexibility of incorporating rules within a slot has been demonstrated in hybrid AI tools such as KEE [Kunz et al 84] and expert system environment such as NExpert [Neuron Data 87]; the object-oriented approach being used to integrate rule-based systems, frame-based systems, graphics, and active values with an object-oriented kernel in the two systems. The

approach is particularly important in modelling unstructured decisions such as those found within the strategic management process. The incomplete knowledge inherent in an unstructured decision domain means that rules may not exist for all situations. The object-oriented approach provides modelling flexibility over pure rule-based model. In addition, rules can be integrated into the object-oriented model as knowledge about the strategic decisions improves.

The object-oriented approach also provides strong support for the customizability requirements discussed in Section 2.7. The idea of building an environment that can be customized to an organization's culture and practice implies a metasystem approach [Chen 88]. Object-oriented modelling approach has been used in metasystems such as MetaView [Sorenson et al 88], MetaEdit [Smolander et al 91], IRDS [Law 88] and IOIS [Chen 88]. The use of an object-oriented approach in the RCIM design is therefore justified.

Although a metasystem is not developed as part of this thesis research, customizability is built into the design of the RCIM through a generalized model. In formulating the RCIM, it is observed that there are significant common properties among a number of RCIM Object Types. For example, all Object Types for modelling the components of a strategic plan, such as the goals and objectives, share a common property for recording whether or not the modelled object (eg. the **Customer-satisfaction** goal) is selected for implementation. These Object Types can be abstracted into a generalized StrategicPlan

Object Type containing the common properties. Similarly, all Object Types used to model the indicators set up by the organization to monitor the environment can be abstracted into a generalized Constraint Object Type. The abstraction allows the RCIM model to be viewed as a much simpler generalized model which can be applied to an organization's strategic management process through customization.

The generalized model of the RCIM is described in Section 3.1. Section 3.2 describes a responsive strategic management process that is adapted from Firdman's Strategic Planning/Plan Execution (SPPE) Process [Firdman 91]. The customization of a RCIM from the generalized model to support a responsive version of Firdman's SPPE Process, and the resultant RCIM are described in Section 3.3.

3.1 The Generalized RCIM

The generalized RCIM is illustrated in Figure 3-1. It consists of two submodels: the Responsive Strategic Plan (RSP) Submodel and the Information Systems (IS) Submodel. The RSP Submodel consists of Object Types for modelling the responsive strategic management process. The IS Submodel consists of Object Types to describe the information systems entities such as application programs and data elements. Discussion of the IS Object Types is available in Chen's IOIS Model [Chen 88] and the IRDS Project [Law 88] and is not addressed in detail in this dissertation. Instead, the discussion is

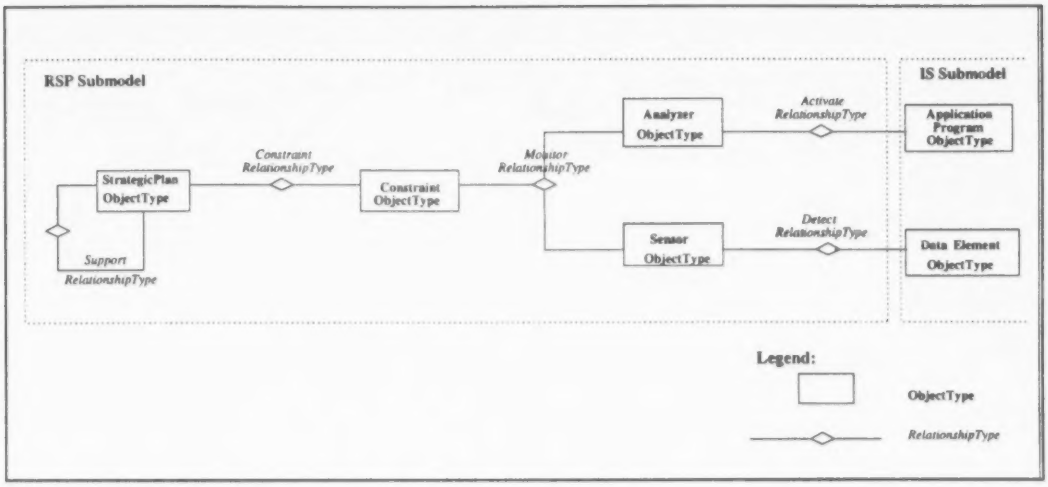

Figure 3-1 Generalized RCIM Model

focused on the generalized Object Types and Relationship Types in the RSP Submodel.

Generalized Object Types

There are four generalized Object Types in the RSP Submodel of the RCIM model: namely the StrategicPlan Object Type, the Constraint Object Type, the Sensor Object Type and the Analyzer Object Type. Figure 3-2 illustrates the inheritance hierarchy for the RCIM generalized Object Types. Each generalized Object Type contains a set of unique attributes for modelling some special aspects of its objects. However, four common attributes are found in all RCIM Object Types, namely, the *name*, *description*, *status*, and *propertiesLog* attributes.

The *name* attribute records the name of an object and is an identifier for the object. An

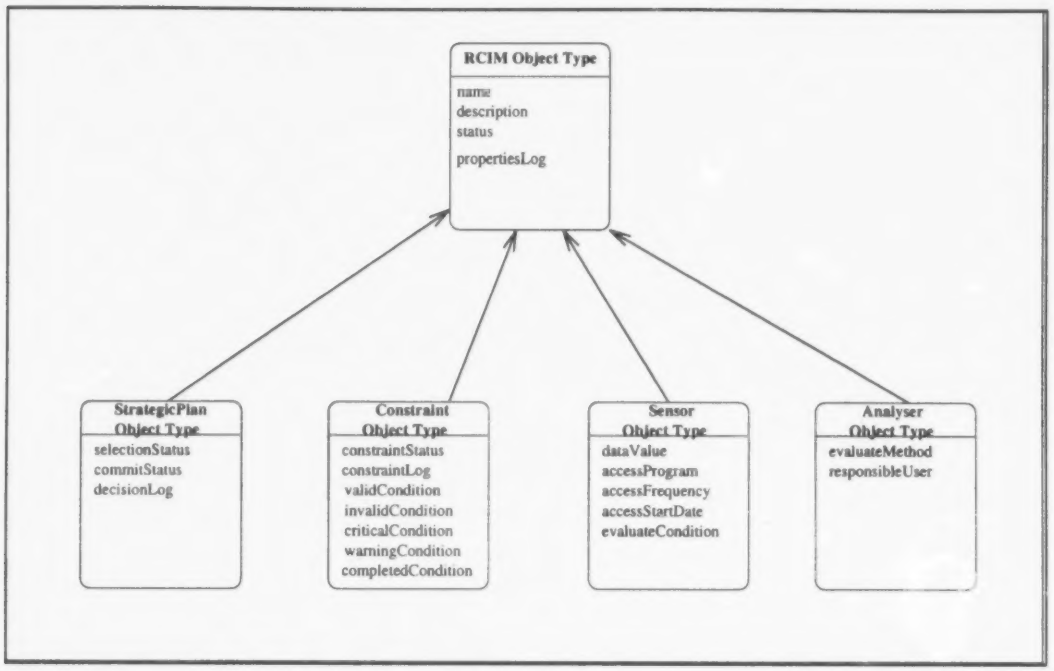

Figure 3-2 Inheritance Hierarchy of the RCIM Object Types

object name must be unique within an Object Type. For example, an organization may choose to use the same identifier **Customer-satisfaction** as both the object name of a *GOAL* object and a *CSF* object, but it cannot have two *CSF* objects with the same name. The object name of an object cannot be changed. The *description* attribute is used to record a short textual description of the object.

The *status* attribute and the *propertiesLog* attributes together support a major part of the decision logging discussed in Section 2.7. All RCIM objects and relationships are kept permanently in the RCIM database. Deleted objects and relationships are not physically removed from the database but are marked with a status of "expired" in the *status*

attribute. Active objects and relationships are marked with a status of "active". Changes to the value of any attribute of the objects or relationships are logged. These data are retained to enable an organization to re-create its strategic plan to a specific point in time in order to retroactively examine its decisions in detail. The history of changes in the objects and relationships provides valuable information towards the study of an organization's decision making practice. Although the use of this data is not addressed in this dissertation, the design feature is built into the RCIM to ensure data is collected for future research.

The RCIM support for decision logging is accomplished differently for user-input attributes versus decision-related attributes of a RCIM Object Type or Relationship Type object. User-input attributes are those attributes that are directly modifiable by the user, ie. the attributes that capture the user's definition of the modelled object. For example, if a *GOAL* object is created to model a specific organization goal, the priority assigned by the user to the goal is captured in the user-input attribute, priority, of the *GOAL* Object Type. Changes to the user-input attributes are therefore user-initiated. In contrast, the decision-related attributes are used to record the decision state of an object, eg. whether or not the object can be selected for implementation. Therefore, the decision-related attribute represents the state of the object as a result of all its user-input attributes and its relationships to other RCIM objects. Changes to the decision-related attributes reflect changes in the strategic plan with respect to changes in the environmental conditions. The nature and frequency of the changes in the two types of attributes are therefore very

different and the logging support for the changes are handled differently. All RCIM Object Types contain some user-input attributes but decision-related attributes are only defined for specific RCIM Object Types. The logging support for the user-input attributes is therefore described in this sub-heading while the additional logging support for the decision-related attributes is described under the sub-heading for the specific RCIM Object Types.

The *propertiesLog* attribute is used to record a history of the creation, changes and deletion of the user-input attributes of the RCIM objects. It is a stack of entries, each recording an incident when some or all of the user-input attributes for the particular object are changed. In other words, the first entry in any *propertiesLog* attribute records a snap shot of the RCIM object or relationship when it is first created.

Each entry in the *propertiesLog* attribute is made up of two components in the form:

(audit header), (a snap shot of the user-input attributes after the change).

The first component is an audit header to record the change action (one of "create", "modify" or "delete"), and the date, time, responsible user and rationale for the action. Recording the rationale of the change action allows an organization to provide extra information for future analysis. The second component of the entry is a snap shot of all user-input attributes of the modelled object after the change. In essence, the last entry of the *propertiesLog* attribute records when the current set of values for the user-input attributes are in effect. Logging a snap shot of all the attributes allows a simple re-

creation of an object to a particular point in time. Otherwise, the object has to be rebuilt from a number of change entries.

StrategicPlan Object Type

A StrategicPlan Object Type is used to model any component of a strategic plan such as a goal, objective or an action plan. It can be associated with other StrategicPlan objects via a Support Relationship Types. This association allows the RCIM to model the hierarchical decomposition of a strategic plan into successive levels of detail. For example, an objective can be decomposed into a set of more detailed objectives. A StrategicPlan object can also be associated with a number of Constraint objects via a Constraint Relationship Type. This association is used to model the environmental monitoring requirements of the StrategicPlan object.

The specialized attributes of the StrategicPlan Object Type are outlined in Figure 3-2, namely, the *selectionStatus*, the *commitStatus* and the *decisionLog*. The first two attributes are decision-related attributes while the *decisionLog* attribute records the changes in the two attributes.

The *selectionStatus* is used for tracking whether a modelled object is "selected", "manually selected", "feasible" or "not feasible" for selection. A StrategicPlan object (e.g. an *OBJECTIVE* object) is "feasible" if all of its associated constraints are valid. It is "not

feasible" if at least one of its associated constraints is invalid. The *selectionStatus* of a "feasible" object can be set to "selected" by the selection algorithm if the object meets the criteria for inclusion in the set of strategic alternatives to be implemented. On the other hand, the "manually selected" *selectionStatus* is set through an explicit user command to designate a RCIM object for inclusion in the set of strategic alternatives to be implemented. The concept of manual selection is non-trivial. To maintain integrity of the overall strategic plan, a RCIM object must first be in a "feasible" state before it can be manually selected. In other words, if one of the constraints associated with a StrategicPlan object is not valid with respect to the environmental conditions, and a user attempts to manually select the object, the command is rejected. The concept and implementation of "manual selection" is discussed in more detail in Section 4.1.

In essence, the *selectionStatus* identifies if an object belongs to the set of strategic alternatives that meets the criteria of the selection algorithm. Within the RSPPE process, the selection criteria include the feasibility of the strategic alternatives and the effective utilization of the available resources to achieve the overall goals. The selection process is an iterative "what-if" process where senior management experiments with different levels of resource commitment, examines the corresponding selected set of strategic alternatives and the overall organization goals that they can accomplish, before a final decision is made with respect to the most appropriate set of strategic alternatives and the optimum level of resource commitment. The *selectionStatus* is therefore a "transient" status that plays a primary role in the selection process.

On the other hand, the *commitStatus* is used to identify if a StrategicPlan object is one that the organization has committed to implement. In this context, the *commitStatus* of a StrategicPlan object can have a value of "not committed", "committed" or "completed". The change in the *commitStatus* of a StrategicPlan object represents a specific management decision or the completion of an action plan. It is noted that in a responsive strategic management process, commitment to implementation is not a permanent decision. Even after an organization is committed to a set of strategic alternatives, if the environmental condition changes, a new set of alternatives must be selected. In essence, the organization is committed to accomplish the overall goals and not the selected strategic alternatives. The need to constantly re-evaluate the *selectionStatus* and *commitStatus* of any StrategicPlan object necessitates both status attributes to be retained.

The two attributes together play a significant role in the modelling capability of the RCIM. Much of the active support and reactivity of the model is accomplished through the collaboration of the StrategicPlan objects and its associated Constraint objects.The collaboration are handled through inter-object messages triggered when one of the object changes state. The states and state changes of the objects are described using state models; and the collaboration between the objects are described using the object communication models. The modelling notations used follow the Schlaer-Mellor Object Analysis and Design Methodology [Schlaer & Mellor 92].

Table 3-1 contains a list of all possible states of a StrategicPlan object. Each state is

identified by a combination of the object's *selectionStatus* and *commitStatus*. Two of the twelve combinations are not possible. For example, a StrategicPlan object that is "not feasible" can never be selected either manually or by the selection algorithm. Similarly, the object can never be "committed to". Therefore, the "not feasible/committed" and "not feasible/selected" states are marked N/A. N/A states are not included in the state model.

selectionStatus	commitStatus	State
feasible	not committed	feasible/ not committed
feasible	committed	feasible/ committed
feasible	completed	feasible/completed
not feasible	not committed	not feasible/not committed
not feasible	committed	N/A
not feasible	completed	N/A
selected	not committed	selected/not committed
selected	committed	selected/committed
selected	completed	selected/completed
manually selected	not committed	manually selected/not committed
manually selected	committed	manually selected/committed
manually selected	completed	manually selected/completed

Note: N/A indicates a state is not possible

Table 3-1 List of States of a StrategicPlan Object

Figure 3-3 is an object communication model illustrating the events occurring between a StrategicPlan object and its related objects. The events are numbered to provide cross reference between the object communication model (Figure 3-3), the state model (Figure 3-4) and the list of activities in response to the events (Table 3-2). Events 1 to 7 occur directly in response to specific user actions to create, select or commit to the object. These events are initiated by the RCIM Editor. Events 8 to 11 occur in response to direct changes in the environment which are detected through the related Constraint Objects.

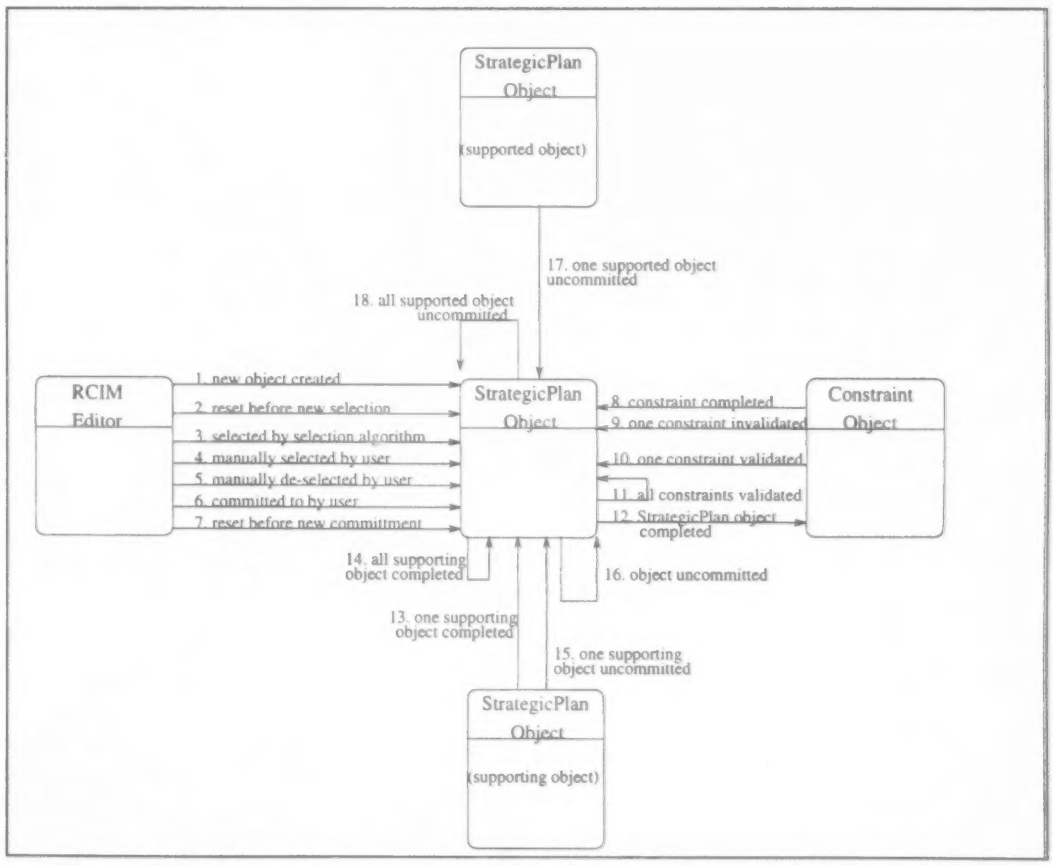

Figure 3-3 Object Communication Model illustrating the Events Occurring between a StrategicPlan Object and its Related Objects

Event 12 occurs when the StrategicPlan object changes its state to "completed". This event triggers all Constraint objects related to the StrategicPlan object to change their state to completed'. Events 13 to 18 occur in response to changes in the related StrategicPlan objects, i.e. the supporting and supported objects.

The dynamic behaviour of a StrategicPlan object is illustrated in the state model in Figure 3-4. All ten states of the StrategicPlan object are illustrated. To reduce the complexities of the state model, only events that lead to a change from one state to another are

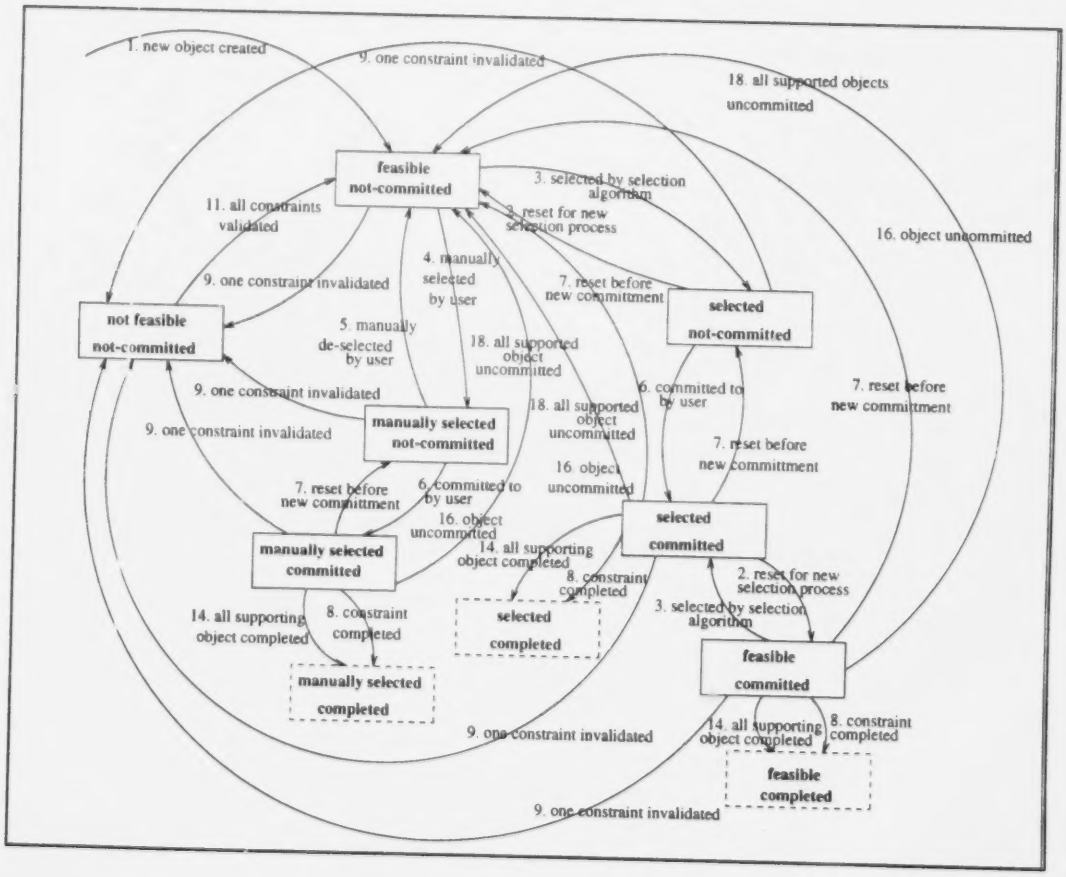
1. new object created
9. one constraint invalidated
18. all supported objects uncommitted
feasible not-committed
3. selected by selection algorithm
11. all constraints validated
2. reset for new selection process
16. object uncommitted
4. manually selected by user
9. one constraint invalidated
7. reset before new committment
not feasible not-committed
selected not-committed
5. manually de-selected by user
18. all supported object uncommitted
9. one constraint invalidated
6. committed to by user
7. reset before new committment
manually selected not-committed
18. all supported object uncommitted
9. one constraint invalidated
7. reset before new committment
16. object uncommitted
7. reset before new committment
6. committed to by user
selected committed
16. object uncommitted
14. all supporting object completed
manually selected committed
8. constraint completed
2. reset for new selection process
3. selected by selection algorithm
14. all supporting object completed
8. constraint completed
selected completed
feasible committed
manually selected completed
9. one constraint invalidated
14. all supporting object completed
8. constraint completed
feasible completed
9. one constraint invalidated

Figure 3-4 State Model of a StrategicPlan Object

illustrated. A StrategicPlan object is created with a default state of "feasible/not committed". If one of the constraint of a StrategicPlan object is invalidated, the state of the StrategicPlan object is changed to "not feasible/not committed". As indicated in Figure 3-4, the state of the StrategicPlan object is also changed if the object is selected by the selection algorithm, selected by a user initiated manual selection command, or committed to implementation, etc. The terminal state is reached when the event "constraint completed" occurs or when all supporting objects of the StrategicPlan object are completed.

In addition to a state change in the StrategicPlan object, an event may trigger additional activities in the RCIM. Table 3-2 lists the additional activities in response to the events occurring to a StrategicPlan object. The activities and the dynamic behaviour of the StrategicPlan objects are described in more details in Chapter 5.

Event to a StrategicPlan Object	**Activities occurring in the StrategicPlan Object in Response to the Event**
1. new object created	New StrategicPlan object created
2. reset for new selection process	Nil
3. selected by selection algorithm	Nil
4. manually selected by user	Nil
5. manually-deselected by user	Nil
6. committed to by user	Nil

7. reset before new commitment	Nil
8. constraint completed	Message is sent to advise user that the object is completed. This state change also triggers state changes in other StrategicPlan objects and Constraint objects associated to the current object. Details of the activities are discussed in Change Scenario #1 in Section 5.5..
9. one constraint invalidated	Message is sent to advise user that the object is no longer feasible. Depending on the state of the object before the event occurs, the message can be a warning or a critical message. The latter may trigger a re-evaluation of the overall strategic plan. Details of the activities are discussed in Change Scenario #2 in Section 5.5.
* 10. one constraint validated	Message to all related Constraint objects to see if they are all valid. If they are, the event "all constraints validated" is triggered for the current object.
11. all constraints validated	Message is sent to advise user that the Strategicplan object is now feasible.
* 12. StrategicPlan object completed	This event triggers state changes in the Constraint objects related to the current object. Details of the activities are discussed in Change Scenario #1 in Section 5.5..
* 13. one supporting object completed	Messages are sent to all supporting objects to see if they are all completed. If they are, the event "all supporting object completed" is sent to the current object. Details of the activities are discussed in Change Scenario #1 in Section 5.5.
14. all supporting objects completed	Message is sent to advise user that the object is completed. This state change also triggers state changes in other StrategicPlan objects and Constraint Objects associated to the current object. Details of the activities are discussed in Change Scenario #1 in Section 5.5.
* 15. one supporting object uncommitted	This event triggers the current object to evaluate if at least one alternative set of its supporting objects is still committed. If none can be found, the event "object uncommitted" is sent to the object itself. Details of the activities are discussed in change scenario #2 in Section 5.5.

16. object uncommitted	Message is sent to advise user that the object is no longer committed to. This state change also triggers state changes in other StrategicPlan objects and Constraint Objects associated to the current object. Details of the activities are discussed in Change Scenario #2 in Section 5.5.
* 17. one supported object uncommitted	This event results from the invalidation of a constraint of a committed object that the current object is supporting. The event triggers an evaluation of all supported objects to see if they are all uncommitted. If they are, the event "all supported objects uncommitted" is sent to the current object. Details are discussed as Change Scenario #2 in Section 5.5.
18. all supported objects uncommitted	Message is sent to advise user that the object is no longer committed to. This state change also triggers state changes in other StrategicPlan objects and Constraint Objects associated to the current object. Details of the activities are discussed in Change Scenario #2 in Section 5.5.

* identifies event that does not lead to a state change

Table 3-2 List of activities in response to events occurring to the StrategicPlan Object

The *decisionLog* is a log of each incident when the *selectionStatus* or *commitStatus* of the modelled StrategicPlan object changes. The structure of the *decisionLog* is similar to that of the *propertiesLog*. Each entry in the stack contains the date, time, party responsible for the change, rationale behind the change, and a snap shot of the new value of the *selectionStatus* and *commitStatus*. The party responsible for the change can be a user if the change is initiated by a user, eg. a manual selection of a specific StrategicPlan object, or it can be initiated by the system, eg. the change to a "not feasible" selection status due to the invalidation of a constraint. The *decisionLog* enables an organization to re-create a snap shot of its overall strategic plan at any time.

Constraint Object Type

A Constraint Object Type is used to model any object that is required to monitor or constrain a StrategicPlan object. Constraint Object Types are the key constructs in the RCIM to allow an organization to model its focused monitoring plan. For example, a *PERFORMANCE INDICATOR* Object Type is defined as a Constraint Object Type to track the performance of an *OBJECTIVE* Object Type (a specialized StrategicPlan Object Type). It provides the capability to automate the monitoring support of the performance of the *OBJECTIVE* object and to effect the changes in the *OBJECTIVE* object if a critical performance condition is met. The environmental monitoring operation requires the collaboration of the Constraint object with the Sensor object and the Analyzer object. The detailed processes involved in defining a Constraint object, a Sensor object and an Analyzer object to monitor a particular StrategicPlan object are described in Section 5.3.

The attributes of a Constraint Object Type are shown in Figure 3-2. In addition to the basic attributes, each Constraint Object Type has a *constraintStatus* attribute, a *constraintLog* attribute and several constraint condition attributes. The *constraintStatus* is used to identify the state of the Constraint object. There are five possible values for the *constraintStatus*, namely, "valid", "invalid", "warning", "critical" and "completed". There are also five constraint condition attributes, namely, the *validCondition*, the *invalidCondition*, the *warningCondition*, the *criticalCondition*, and the *completedCondition* attributes. Each of the constraint condition attributes allows the user to specify the

conditions that trigger a state change in the particular Constraint object to the corresponding *constraintStatus*.

The *constraintLog* is a log of each incident when the *constraintStatus* changes. The structure of the *constraintLog* is slightly different from the *decisionLog* and the *propertiesLog* since all changes to the *constraintLog* are initiated by the system. Each entry in the log contains the date, time of the status change, and the new value of the *constraintStatus*. Thus, the *constraintLog* enables an organization to re-create a snap shot of the constraint at a particular point in time.

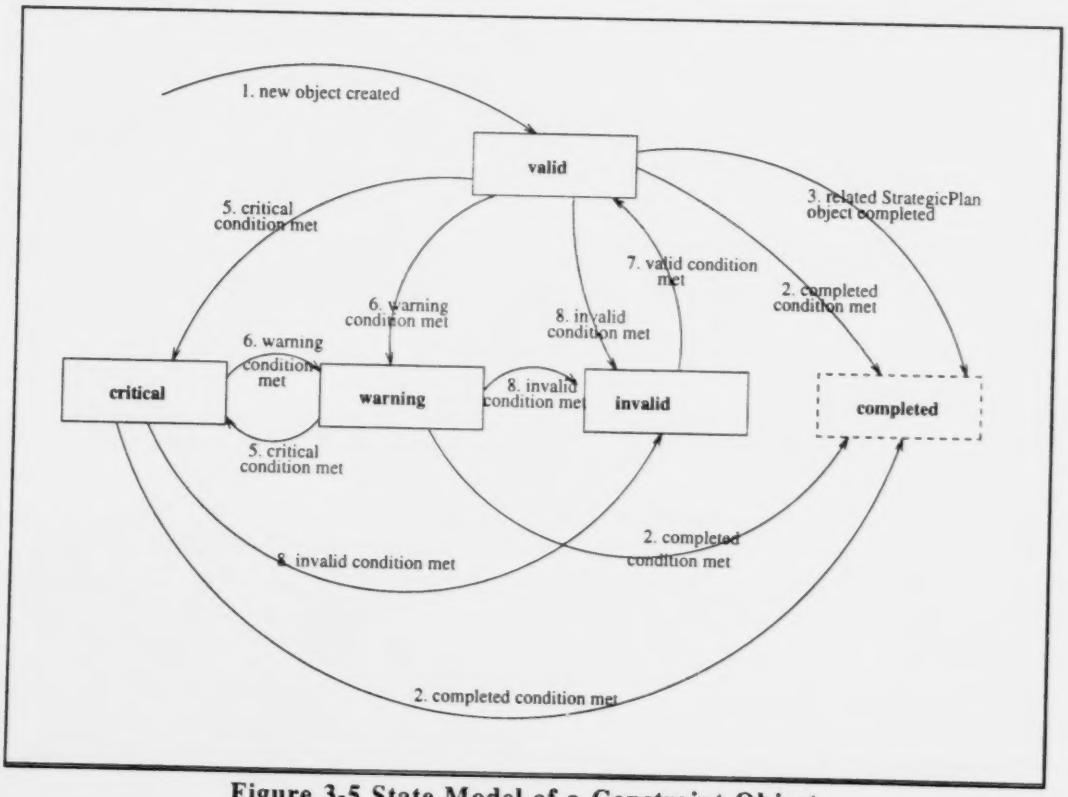

Figure 3-5 State Model of a Constraint Object

Figure 3-5 is a state model of a Constraint object. The events are numbered to enable cross-referencing of the events between the state model (Figure 3-5), the object communication model (Figure 3-6) and the list of activities in response to the events (Table 3-3). A Constraint object is in a "valid" state when it is created by the user using the RCIM Editor (Event 1). As environmental condition changes, the condition is identified by the Analyzer object. Appropriate event is sent by the Analyzer object to trigger the Constraint object to change its state (Events 2, 5, 6, 7 and 8). The response to Events 5 to 8 are straight forward. The response to Event 2 is the most complicated and is explained in detail below.

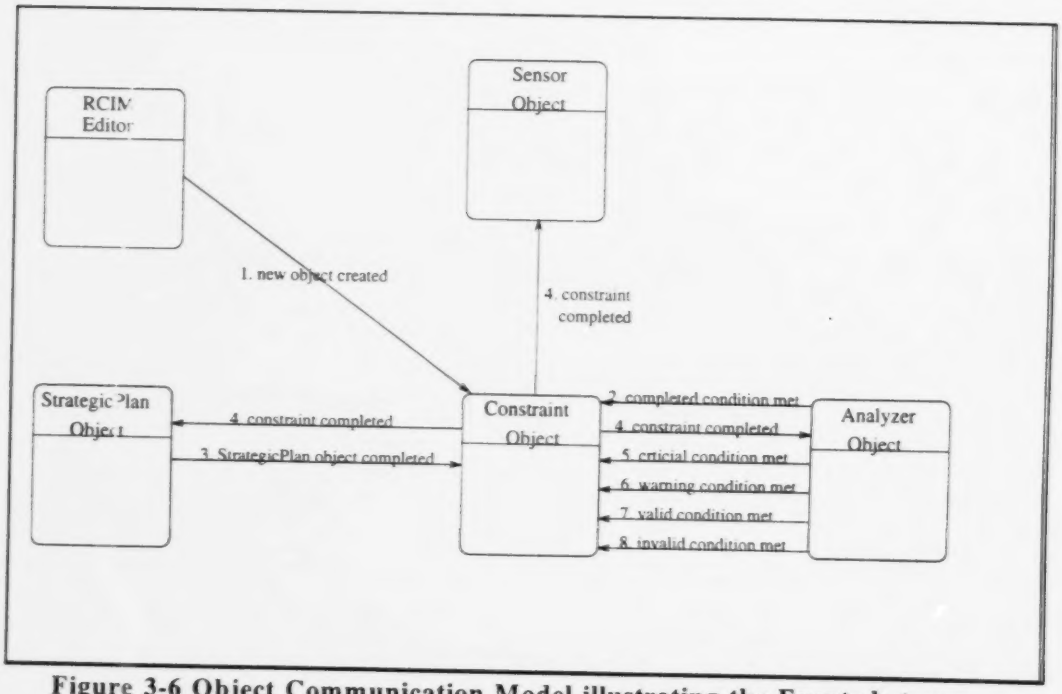

Figure 3-6 Object Communication Model illustrating the Events between a Constraint Object and its related objects

When the Analyzer object recognizes the satisfaction of the *completedCondition* specified in the Constraint object, the event "completed condition met" (Event 2) occurred in the Constraint object. This triggers a state change of the Constraint object to "completed" plus the event "constraint completed" being sent to its related StrategicPlan objects, its Sensor and Analyzer objects. The "constraint completed" event results in the change in state of the StrategicPlan object to "completed" (see Table 3-2 for detail). The dependency between the Sensor and Analyzer objects and the Constraint object are removed as a result of the "constraint completed" event. In essence, a "completed" constraint signifies the completion of the related StrategicPlan object, at which point the environmental monitoring with respect to that particular object can be discontinued.

Events to a Constraint Object	**Activities in response to the events occurring to the Constraint Object**
1. new object created	New Constraint object created
2. completed condition met	Message is sent to advise user that the constraint is now completed. This event also triggers the event "constraint completed" to be sent to the related StrategicPlan object, Sensor and Analyzer objects.
3. StrategicPlan object completed	If all StrategicPlan objects for this constraint are completed, a message is sent to advise user that the constraint is now completed. This event also triggers the event "constraint completed" to be sent to the related StrategicPlan object, Sensor and Analyzer objects. Otherwise, ignore.

4. Constraint completed	Message is sent to the related Sensor and Analyzer objects to remove the need for further sensing and analyzing of the constraint conditions. If all related constraints for the Sensor and Analyzer objects are completed, a message is sent to advise user and request that the objects be "expired". Otherwise, the Sensor will continue to access the specified data elements although it will not be able to trigger any analysis of the conditions or change in any constraint conditions.
5. critical condition met	Message is sent to advise user that a critical condition in this Constraint object is met. User is advised to promptly response.
6. warning condition met	Message is sent to advise user that a warning condition in this Constraint object is met. User is advised to consider if response is necessary.
7. valid condition met	Message is sent to advise user that the constraint is now validated (from an invalid state). User is advised to re-plan. This event also triggers the event "one constraint validated" to be sent to the related StrategicPlan object.
8. invalid condition met	Message is sent to advise user that the constraint is now invalidated. User is advised to follow up the impact. This event also triggers the event "one constraint invalidated" to be sent to the related StrategicPlan object.

Table 3-3 List of Activities in response to the events occurring to the Constraint Object

Not all constraint statuses are inherited by all specialized Constraint Object Types. Each specialized Constraint Object Type inherits only the subset of the *constraintStatus* values that is meaningful to it. For example, a strategic assumption may only need to inherit the values "valid" or "invalid" for its *constraintStatus*. The *constraintStatus* for the *ASSUMPTION* Object Type can be re-defined to include only those two values. Consequently, only the *validCondition* and the *invalidCondition* need to be specified for

each *ASSUMPTION* object created. The customization process of the generalized model is described in more detail in Section 3.3.

Sensor Object Type

The Sensor Object Type is used for modelling objects that perform a function similar to that of a robotic sensor in the architecture of the reactive reasoning and planning system. It provides the linkage for the RCIM to make use of the organization's information systems resources as a monitoring support for the strategic management process. In the RCIM, information systems resources are modelled as DataElement and ApplicationProgram Object Types.

The attributes of a Sensor Object Type are shown in Figure 3-2. The *dataValue* attribute holds the "last-scanned" value of the data element that is being monitored. An example of such a data element may be the Customer-Rating field in the Customer Relationship Assessment Database. As indicated in the generalized RCIM Model (Figure 3-1), this data element is modelled as a DataElement object that is related to the Sensor object.

The *accessStartDate* attribute identifies when the focused monitoring support for the associated Constraint object must be initiated. Since the implementation of a strategic plan can span over a period of time, an organization may not want to initiate the focused monitoring of constraints such as *PERFORMANCE INDICATOR* until implementation

time. The *accessProgram* attribute holds the information necessary for physically accessing and retrieving the current value of the data element, while the *accessFrequency* attribute identifies the frequency of the retrieval.

The primary role of the Sensor object is to determine if the changes in the data element need to be analyzed in detail. In some cases, no change in the value of a data element may signify a critical condition, eg. a zero increase in the YTD Annual Sales. An organization can therefore specify through the *evaluateCondition* attribute if the Analyzer object needs to be executed only if changes are detected by the Sensor object or regardless of any changes. The former causes the Sensor object to retrieve the appropriate data values at scheduled intervals and compare the new value with the "last scanned" value. If the value is changed, the Sensor object "requests" the collaboration of the related Analyzer object to determine if the situation meets one of the constraint conditions defined in the related Constraint objects.

Analyzer Object Type

The Analyzer Object Type and the Sensor Object Type together models the partitioned architecture described in Section 2.2. The Analyzer Object Type provides the means to utilize the organization's application programs (modelled by the ApplicationProgram Object Type) to analyze the impact of the changes detected in the organization environment.

The decision to use an Analyzer Object Type to facilitate the linkage between a Constraint Object Type to the ApplicationProgram Object Type, instead of directly linking the latter two Object Types is two-fold. First, the Analyzer Object Type is responsible for initiating an appropriate change in the *constraintStatus* of the related Constraint Object Type based on the analysis of the changes detected by the Sensor Object. It is therefore an "active" Object Type. An ApplicationProgram Object Type is defined in the Information Systems Submodel. It may be part of a transaction processing system and is typically not an "active" object. In fact, it may not be technically possible to modify some legacy systems to incorporate the notion of "active" objects.

Second, there are basically two types of analysis programs. In a situation where an organization is knowledgeable about the impact of the changes, the analysis may be automated by an application program. In other situations, the complexity of the changes may require subjective analysis by senior management or designated information experts. A user interface routine is then required for manual input of the result of the analysis into the system. The incorporation of user interface routines through the use of the Analyzer Object Type provides a means of coordinating and delegating the analysis activities within the organization.

Furthermore, even if the analysis is well defined, it is unlikely that an application program is readily available to provide the necessary analysis. Once the analysis requirements has been determined, an user interface routine may be required in the interim until an

application program can be developed or modified to handle the analysis. This interim user interface routine can be replaced with the appropriate application program once development is completed. The use of an Analyzer Object Type reduces the impact of these changes to the information systems model.

The *evaluationMethod* attribute shown in Figure 3-2 identifies if a manual user interface is in place. The *responsibleUser* attribute allows the organization to delegate the manual analysis of the constraint to a member of the environment monitoring group. The designated user is prompted to manually evaluate the specified environmental condition and input the result of the evaluation via the user interface whenever the Analyzer object is executed.

Generalized Relationship Types

There are a total of five generalized Relationship Types in the RCIM model (as shown in Figure 3-1): the Support, Constraint, Monitor, Activate and Detect Relationship Types. Each RCIM Relationship Type models a unique relationship between two or more Object Types. Figure 3-7 illustrates the inheritance hierarchy of the RCIM Relationship Types.

The behaviour of the RCIM Relationship Types is simple when compared to the Object Types. The primary function of the Relationship Types is to support the retrieval of

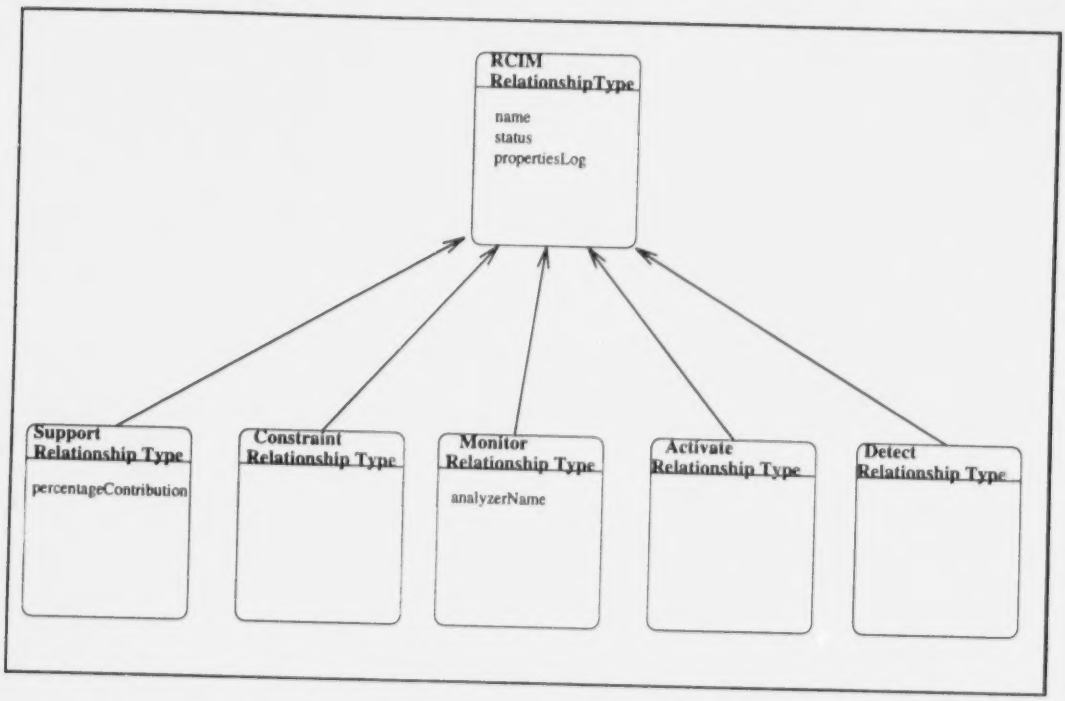

Figure 3-7 Inheritance Hierarchy of the RCIM Relationship Types

related objects. In addition, there is a provision within each Relationship Type to model some special properties of the relationship. There are three attributes in all RCIM Relationship Types, namely, the *name*, *status* and *propertiesLog* attributes. The *name* attribute is an identifier for the relationship and is unique within the Relationship Type. The name of any relationship is a compound name consisting of the names of the objects related by the given relationship. The elements in the compound name may differ according to the Relationship Type. This is discussed in more detail for each of the Relationship Type. The *status* and *propertiesLog* attributes are similar to the ones defined for the RCIM Object Types; the *status* attribute is used to identify if a relationship is "active" or "expired", and the *propertiesLog* captures all changes to the user-input attributes of the relationship. Only a few of the Relationship Types have user-input

attributes. They are described under the individual Relationship Type.

Support Relationship Type

The Support Relationship Type is used to model the relationship between two StrategicPlan objects. Each relationship represents the decomposition of one StrategicPlan object into its supporting objects, eg. an objective (modelled as an *OBJECTIVE* object) is decomposed into several more detailed objectives (modelled as other *OBJECTIVE* objects). Each Support Relationship Type has a user-input attribute, the *percentageContribution* attribute, which captures the contribution of a supporting object to the object from which it is decomposed. .

There are two design restrictions for the decomposition of any object. First, a decomposition is not complete unless the supported (higher-level) StrategicPlan object is "fully supported" by its set of supporting objects. A set of StrategicPlan objects is said to "fully support" a StrategicPlan object if-and-only-if the accomplishment of all objects in the set is equivalent to the accomplishment of the supported object. The accomplishment of a StrategicPlan object is indicated by a commitStatus of "completed". In other words, if an objective is decomposed into a set of "fully supporting" action plans, then the objective is accomplished (i.e. its commitStatus is set to "completed") if all its action plans are successfully accomplished (i.e. the commitStatus of all *ACTION PLAN* objects are set to "completed"). A set of StrategicPlan objects "fully support" a

StrategicPlan object if the sum of all *percentageContribution* attributes equals to 100.

Second, the design must allow multiple alternative sets of "fully supporting" objects to support a single object. Each alternative set is identified by a unique Alternative identifier. This is necessary because an object may be decomposed into more than one set of strategic alternatives. For example, assume an *OBJECTIVE* object is related to one or more sets of *OBJECTIVE* objects. Each set of *OBJECTIVE* objects fully supports the higher level *OBJECTIVE* object. In addition, the multiple sets of objects supporting the same object do not have to be mutually exclusive. In other words, an *OBJECTIVE* object can be included in more than one alternative supporting the same *OBJECTIVE* object.

These two design restrictions imply that each Support relationship is only uniquely defined by the supported object, the supporting object and the alternative in which the supporting object belongs. The name of the relationship is therefore a compound name of the form: (name of supported object, identifier of the alternative, name of the supporting object).

Constraint Relationship Types

A Constraint Relationship Type is a binary relationship defined to associate a StrategicPlan Object Type with a Constraint Object Type (refer to Figure 3-1). Unlike the Support Relationship Type, it does not support multiple sets of alternatives. Therefore,

each Constraint relationship can be uniquely identified by the compound name consisting of the name of the StrategicPlan object and the name of the related Constraint object.

The Constraint relationship is a n by m relationship between the instances of the two Object Types. For example, an *OBJECTIVE* object can be measured by more than one *PERFORMANCE INDICATOR* object. Similarly, one *PERFORMANCE INDICATOR* object can be used to measure the performance of more than one *OBJECTIVE* objects. There are no common properties associated with the generalized Constraint Relationship Type. However, special properties may be defined for individual specialized Constraint Relationship Type. For example, the *ACTION-PLAN*-**is-constrained-by**-*RESOURCE* relationship has an attribute, *unitsOfResource*, to capture the number of units of the related resource required for the action plan.

Monitor Relationship Type

The Monitor Relationship Type is a three-way relationship defined to associate a Constraint Object Type with a Sensor Object Type and an Analyzer Object Type. However, the relationship is uniquely defined by the Constraint object and the Sensor object. The name of the Monitor relationship is therefore a compound name consisting of the names of the Constraint object and Sensor object.

A unique Analyzer object is identified to detect and evaluate the impact of specific

environmental changes based on the constraint conditions identified in the Constraint object. The name of this Analyzer object is captured in the *analyzerName* attribute of the Monitor Relationship Type. This name can then be used to retrieve the Analyzer object. No other common attributes are defined for the Monitor Relationship Type.

Detect Relationship Type and the Activate Relationship Type

The Detect Relationship Type is a binary relationship to associate a Sensor Object Type with a Data Element Object Type (refer to Figure 3-1). The name of the Detect relationship is a compound name consisting of the name of the two related objects. The Detect relationship is a n-to-1 relationship between the instances of the two Object Types. In other words, a Sensor object is assigned to detect the changes in a specific DataElement object but a specific DataElement object can be the focus of more than one Sensor object. Similarly, the Activate Relationship Type supports a n-to-1 relationship associating a Analyzer Object Type with an ApplicationProgram Object Type. The name of each Activate relationship is made up of the names of the two related objects.

The Detect and Activate relationships together plays an important role in the conceptual design of the RCIM. They allow the organization to deploy its existing information systems resources to support the strategic management process. By giving management the ability to access the organization-wide information systems model and to link existing applications to the RSP Submodel through creation or modification of a Relationship Type

object, the user can quickly implement changes in the focused monitoring support.

The discussion of the generalized RCIM Object Types and Relationship Types provides an overview of the design concepts of the RCIM. However, this generalized design has to be customized by an organization to its strategic management process. In Section 3.2, a responsive strategic management process adapted from Firdman's Strategic Planning /Plan Execution (SPPE) process is described. A RCIM for the responsive SPPE process is then described in Section 3.3 as an example to illustrate how the generalized model can be customized.

3.2 The Responsive Strategic Planning/Plan Execution (RSPPE) Process

Firdman s SPPE Process

The Responsive Strategic Planning/Plan Execution (RSPPE) Process is based on Firdman's SPPE Process [Firdman 91]. Firdman describes the SPPE process as a strategic management approach to translate the corporate vision into a set of implementable action programs. The basic process consists of five steps:

1. Formulate a set of high level goal statements[1], consisting of a few easy-to-

[1] Firdman used the term Corporate-specific Strategic Objectives (CSOs) to identify the goal statements. Although it is possible to customize the RCIM to use this term, it is felt that the more common term, Goal is more intuitive and presents less conflict with the other RCIM terms once the SPPE is modified to the

understand statements of what the organization wants to accomplish.

2. Put together a capable strategic planning team responsible for translating the goal statements into an implementable action plan.
3. Develop a set of alternative strategic plans with rough estimates of their cost-effectiveness.
4. Expand the selected strategic plan into a hierarchy of increasingly detailed action plans.
5. Implement and monitor the selected action plans, evaluate the ongoing results, and change them if necessary.

Firdman identified four conditions that must be satisfied by the SPPE process and the resulting strategic plan:

1. The resulting strategic plan must encompass both the organization and its immediate business environment.
2. The SPPE process must be a continuous effort rather than just a one-shot effort. The only way the organization can be flexible enough to react quickly to imminent changes is to have a top-down, easily updated strategic plan with deferred low-level decisions.
3. The resulting strategic plan must account for the future, rather than the present state of the organization. All IS-related endeavour must take into account the directions in which the organization will develop in the next three to five years.

RSPPE. The term CSO is therefore not used in this section.

4. The resulting strategic plan must be top-down rather than bottom-up. It should adopt a "Think Big ---- Start Small" rather than a "Think Small" strategy. All tactical, short-term, resource-limited decisions have to be made in the broader context of the overall long-term strategic plan.

The Responsive Strategic Planning/Plan Execution (RSPPE) Process

The process and the conditions described by Firdman illustrates a typical comprehensive strategic planning process where significant amount of information is considered in generating the strategic plans. However, while Firdman recognize the importance of a continuous planning effort (condition #2), his process recommends the selection of a strategic plan based on rough estimates of the cost-effectiveness of the alternative plans (step #3 of the process) and then focusing the planning effort exclusively to develop the detailed action for this selected plan (step #4 of the process). By exploring only one selected plan, the organization loses the flexibility to respond to changes in the environment with alternative plans. According to Bourgeois and Eisenhardt's empirical study [Bourgeois & Eisenhardt 88], the organization that explores multiple alternatives simultaneously is more responsive in a dynamic environment.

To be responsive, the following Responsive Strategic Planning/Plan Execution (RSPPE) Process is constructed:

1. Formulate a set of high level goal statements, consisting of a few easy-to-

understand statements of what the organization wants to accomplish.

2. Put together a capable strategic planning team responsible for translating the goal statements into an implementable action program.

3. Identify the critical areas to focus the organization's planning effort.

3a. Enter the strategic planning information into the RCIM data base, beginning with the goals and continuing as information becomes available.

3b. Identify a set of Critical Success Factors (CSFs) for the goals in order to focus the organization's planning effort in a selected number of areas.

3c. Identify a set of performance indicators that can be used by the organization to measure its progress towards achieving the CSFs and goals.

3d. Develop a set of alternative strategic plans to achieve the CSFs.

4. Develop the strategic alternatives to accomplish the organization goals and CSFs.

4a. Expand each alternative strategic plan into a hierarchy of increasingly detailed strategic alternatives. Each strategic alternative identifies an intermediate objective or an action plan that must be achieved in order to achieve the higher level objective. The emphasis of the expansion is on identifying the intermediate objectives and deferring the identification of actual action plans to the lowest level of the hierarchy, and on exploring as many alternatives as possible.

4b. Identify the performance indicators that can be used to monitor the progress towards the accomplishment of each objective and the related information systems resources (application programs, data elements etc) to support the monitoring process.

4c. Identify the assumptions behind each proposed objective, and the information systems resources required to monitor any change in the status of the assumptions.

4d. Identify the resource requirements and progress indicators of each action plan, and the information systems resources required to monitor the resource availability and the progress of the action plans.

5. Select a set of strategic alternatives based on their identified resource estimates and their efficiency in accomplishing the overall goals.

6. Finalize the set of selected strategic alternatives and commit resources to the implementation of the action plans.

7. Manage the implementation of the responsive strategic plan.

7a. Implement the committed action plans.

7b. Monitor and evaluate the progress towards the overall goals continuously, making appropriate changes to the RCIM where necessary.

7c. Repeat steps 5, 6 and 7a where necessary to ensure that the best set of strategic alternatives is selected for implementation to accomplish the overall goals.

Comparison of the SPPE process and the RSPPE process

Although the RSPPE appears to be quite different from Firdman's SPPE, many of the detailed steps within the development of the strategic plan in the RSPPE process (specifically steps 3a, 3c, 4b, 4c, and 4d) relate to steps required to build up the RCIM

database. A closer examination reveals that these steps, except for step 3a, are all implicitly incorporated in step 5 of the SPPE process to support the monitoring of the action plans.

Step 3b is added to incorporate Rockart's CSF method [Rockart 79] as part of the RSPPE process. Goal statements are generally high level and directional in nature. It is difficult to measure the progress towards the goals unless they are refined to provide more specific targets. Critical success factors (CSFs) assist in refining the organization goals into specific target areas for detailed planning to proceed. The CSF method has been incorporated in many strategic planning processes as a mechanism to help the organization translate its goals to action plans [Chen et al 91, Sanders 92, Lee & Leifer 92, Volonino & Watson 91]. It is also used in the development of the ITRI Strategic Plan, which is used as an example in phase 3 of this research. The incorporation of the CSF method in the RSPPE process adds to the effectiveness of the process and allows the customized RCIM to be used for the ITRI example.

Step 3d in the RSPPE process relates closely to step 3 in the SPPE process, although the calculation of the resource estimates of the alternative strategic plan is deferred to step 4d when the organization has more information about the alternative strategic plans. This deference is crucial as resource estimate is a typical constraint on an action plan and is subject to frequent changes in the real world. Deferring the calculation of the resource estimates allows any changes in the resource estimates of an action plan be monitored and

reflected in the overall plan appropriately.

Step 4a captures the essence of the responsive strategic management process. It stresses the expansion of all alternative strategic plans in a RSPPE Process instead of a single selected strategic plan in step 4 of the SPPE Process. The concurrent expansion of all alternative strategic plans provides an organization with a responsive plan that can better withstand the changes in a dynamic environment. Based on the reactive reasoning and planning concepts, the emphasis on expanding the responsive strategic plan into intermediate objectives instead of detailed action plans is crucial in increasing the responsiveness of the plan.

Steps 4e and 4f of the RSPPE process are implicit in step 4 of Firdman's SPPE process. Firdman describes a selection algorithm for selecting a set of action plans that together will accomplish the overall goals in a most efficient and effective ways. This algorithm is discussed in detail in the next subsection. The algorithm is adopted in step 5 of the RSPPE process. The algorithm is used once in step 3 of the SPPE process to select a single strategic plan on which all subsequent planning and management activities are focused. However, the algorithm is used repeatedly in the RSPPE process to ensure that the set of selected strategic alternatives is constantly updated with respect to the environmental conditions and remains as the best choice to accomplish the overall goals.

Steps 7a, 7b and 7c of the RSPPE process are essentially a detailed breakdown of step

5 of the SPPE process. However, there is a major difference between the two processes. The effort spent in building up the RCIM data base throughout the RSPPE process ensures that the monitoring of the progress is planned and supported, starting in step 3a. However, the planning of the monitoring activities are implicit within step 5 of the SPPE process. We claim that this late planning often results in a less effective monitoring process, as manpower is split between implementing the committed-to action plans and planning the monitoring activities. Ineffective monitoring leads to a loss in responsiveness. Step 7 of the RSPPE process, in particular, stresses the importance of continuously re-evaluating the set of selected strategic alternatives and updating it in response to the changing environmental conditions. This is the essence of the responsive strategic management process.

Firdman's Selection Algorithm

Firdman [Firdman 91] describes a selection algorithm that can be used within the SPPE process to select a set of action plans that supports a maximum number of the highest priority organization goals within the constraints of available resources. In an organization setting, resource limitation is a reality. Very often, an organization can only allocate a specific amount of resource for the implementation of the action plans and the selection of the action plans must stop before this limitation is reached. The algorithm recognizes the complex relationships that exist among the strategic alternatives: that there is often more than one set of action plans for accomplishing each objective; each plan differs in

its resource requirements and constraints, and in its effectiveness in supporting the objectives; each plan may support more than one objective; and all plans compete for a common pool of limited organization resources. Figure 3-8 graphically illustrates an example network of goals, objectives, and action plans. Multiple sets of strategic alternatives for accomplishing the set of goals are included in the network. For example, the set containing action plans **Action Plan1**, **Action Plan2** and **Action Plan3** and the set containing **Action Plan4** and **Action Plan5** represent two alternative proposals to accomplish objective **Objective1**; while **Objective1** is the single objective which if accomplished will result in goal **Goal1** being accomplished, and **Objective2** is a single objective required to accomplish goal **Goal2**.

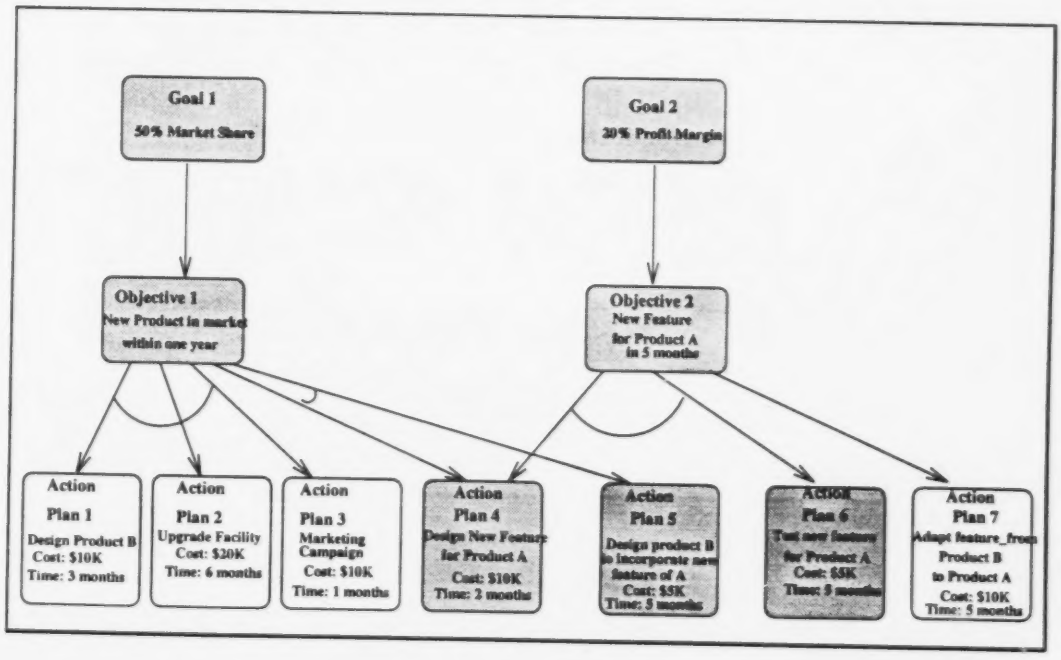

Figure 3-8 Example of a Goal-Objective-Action Plan Network

Firdman's selection algorithm consists of the following steps:

1. Consider a set of organization goals such that the goals are prioritized according to their relative importance.

2. Starting with the goal with the highest priority, the resource estimate required to support each set of strategic alternatives is calculated. The strategic alternatives in the set with the lowest resource requirements are included in the set of selected strategic alternatives.

3. Considering the goal with the next highest priority, the additional resources required to support each set of strategic alternatives for this goal is calculated and the strategic alternatives in the set with the lowest additional resource requirements are added to the set of selected strategic alternatives. The additional resources required to support a set of strategic alternatives for a goal is the sum of the resource estimates of all strategic alternatives in the set that have not been selected to support a higher priority goal. If the inclusion of a strategic alternative results in the total resource requirements exceeding the total available resources, the selection process is terminated.

4. Repeat step 3 until all goals have been considered. The set of selected strategic alternatives at the end of the selection process represents the set of strategic alternatives that together will achieve the organization goals with the lowest amount of resource requirements.

The operation of the algorithm can be visualized using the simple example shown in Figure 3-8 Assuming **Goal1** has a higher priority than **Goal2**. The resource requirements

of the two sets of strategic alternatives supporting the objective **Objective1**(the single objective for the goal **Goal1**) are 40K (for **Action Plan1**, **Action Plan2** and **Action Plan3**) and 15K (for **Action Plan4** and **Action Plan5**) respectively. The strategic alternatives **Action Plan4** and **Action Plan5** are therefore included in the set of selected strategic alternatives. However, when considering the case for the goal **Goal2**, the additional resource requirements for the two sets of strategic alternatives supporting **Objective2** are 5K (for **Action Plan4** and **Action Plan6**) and 10K (for **Action Plan7**) respectively. The additional resource requirements for (**Action Plan4** and **Action Plan6**) is 5K instead of 15K because **Action Plan4** has already been selected to support **Objective1**. The set of selected strategic alternatives for supporting **Goal1** and **Goal2** is therefore the set consisting of objectives **Objective1** and **Objective2** and the action plans **Action Plan4**, **Action Plan5** and **Action Plan6**.

Firdman's algorithm provides a mechanism to select a set of strategic alternatives based primarily on financial resource estimates. The customized RCIM described in Section 3.3 is formulated to support this selection algorithm. Conceivably, algorithms can be developed to base the selection on other types of constraints, and the RCIM will need to be customized to support the new algorithms.

3.3 The Customized RCIM for the RSPPE Process

There are several steps in customizing a RCIM for a specific strategic management

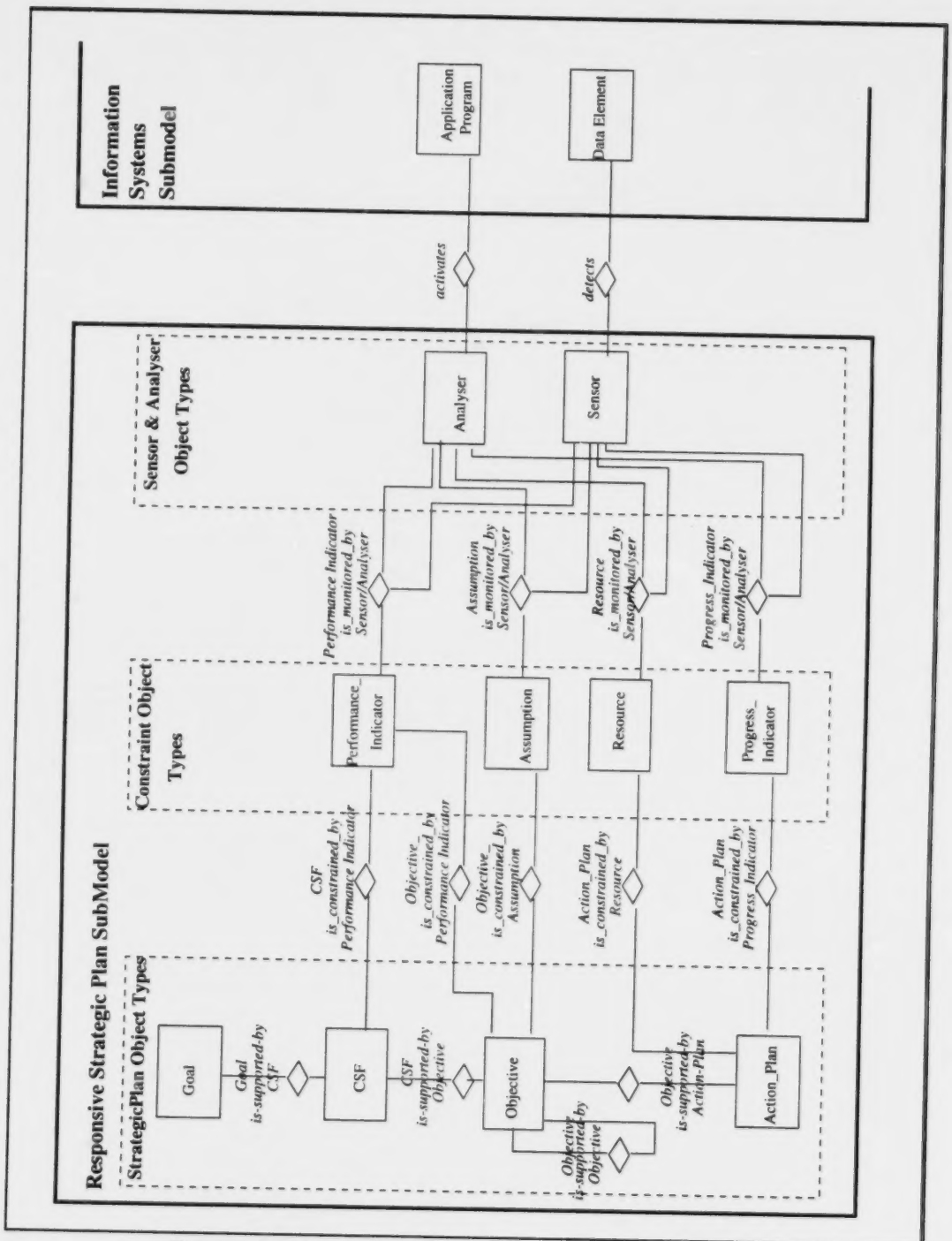

Figure 3-9 Responsive Corporate Information Model

process. The customization starts with the generalized RCIM shown in Figure 3-1. The steps involved are briefly outlined below, using Firdman's SPPE process as an example. The customized RCIM is shown in Figure 3-9.

The steps for customizing a RCIM include:

1. Define the responsive strategic management process.

For most organizations, the first step of the customization involves defining the existing strategic management process and modifying it to incorporate the responsive concepts. The modification of the SPPE Process to the RSPPE Process has been discussed in Section 3.2. The remaining steps (Steps 2 to 8) involve elaborating on the definition of each of the generalized Object Types and Relationship Types illustrated in Figure 3-1 into the specialized Object Types and Relationship Types illustrated in Figure 3-9.

2. Identify all specialized StrategicPlan Object Types that must be modelled in the responsive strategic management process and the unique attributes of each specialized Object Types.

Based on the RSPPE process, four specialized StrategicPlan Object Types are identified, namely, the *GOAL*, *CSF*, *OBJECTIVE* and *ACTION PLAN* Object Types. Figure 3-10 illustrates the inheritance hierarchy of the specialized StrategicPlan Object Type and their unique attributes. The *priority* attribute of the *GOAL* Object Type is used to identify the relative importance of the *GOAL* object. No unique attributes has been identified for the *CSF* Object Type. There are two additional attributes for the *OBJECTIVE* Object Type,

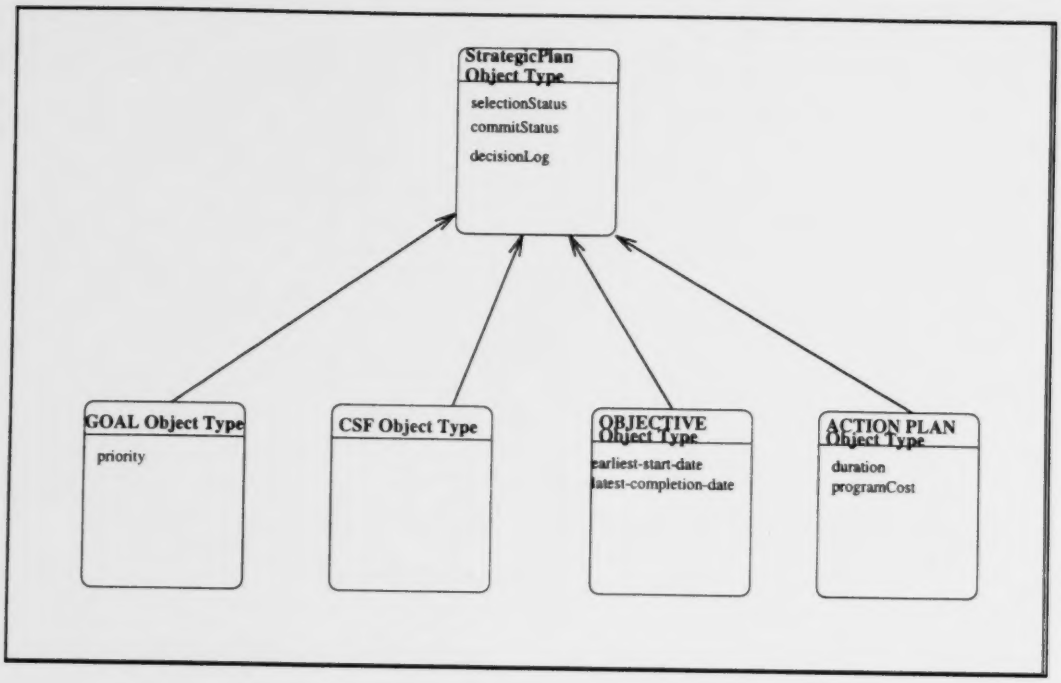

Figure 3-10 Inheritance Hierarchy of the StrategicPlan Object Type

namely, the *earliest-start-date* and the *latest-completion-date*. The two dates allow the organization to restrict the decomposition of an objective into its supporting strategic alternatives such that all supporting alternatives reside within the two dates. The *ACTION PLAN* Object Type consists of a *duration* attribute to record the estimated duration of the action plan in days and a *programCost* attribute to keep track of the estimated cost of the resources required for the action plan.

3. Identify the specialized Support Relationship Type between the StrategicPlan Object Types.

Four Support Relationship Object Types are identified, namely, the *GOAL-**is-supported-by**-CSF*, *CSF-**is-supported-by**-OBJECTIVE*, *OBJECTIVE-**is-supported-by**-OBJECTIVE*,

and *OBJECTIVE*-**is-supported-by**-*ACTION-PLAN* Relationship Types. The *OBJECTIVE*-***is-supported-by***-*OBJECTIVE* Relationship Type enables the modelling of recursive decomposition of an objective into a hierarchy of sub-objectives. As indicated in Section 2.1, the reactive capability of a reactive reasoning and planning system depends on the extent to which goals are decomposed. The recursive decomposition supported by the *OBJECTIVE*-***is-supported-by***-*OBJECTIVE* Relationship Type is therefore important to the responsiveness of the customized RCIM model of the RSPPE process. All Support Relationship Types are identical in structure, except for the Object Types associated in the respective relationships.

4. Identify the specialized Constraint Object Types that must be modelled and their attributes.

To identify the specialized Constraint Object Types, examine each specialized StrategicPlan Object Type to determine the different types of constraints that must be monitored in order to successfully accomplish a plan. In the RSPPE, it is determined that performance indicators must be established to monitor the progress of the CSFs and the objectives, and progress indicators must be set up to monitor the progress of action plans. In addition, the proposed objectives are often based on specific assumptions about the environment. If these assumptions are invalid, the objectives may not be viable. Therefore, it is necessary to set up Object Types to monitor the strategic assumptions. At the same time, the viability of the action plans depend on the resource requirements and their availability. A Constraint Object Type to monitor resource requirements is therefore

necessary.

Four specialized Constraint Object Types are therefore identified, namely, the *PERFORMANCE-INDICATOR, ASSUMPTION, RESOURCE* and *PROGRESS-INDICATOR* Object Types. Figure 3-11 illustrates the inheritance hierarchy of the Constraint Object Types. All Constraint Object Types inherit the *constraintStatus* attribute. However, a different subset of the *constraintStatus* values are inherited in each specialized Constraint Object Type to reflect the conditions that are appropriate to its objects. For example, the "valid", "warning" and "critical" conditions are appropriate to both the performance and progress indicators, but the "completed" condition is only meaningful for the progress indicators. The specialization results in a more intuitive model.

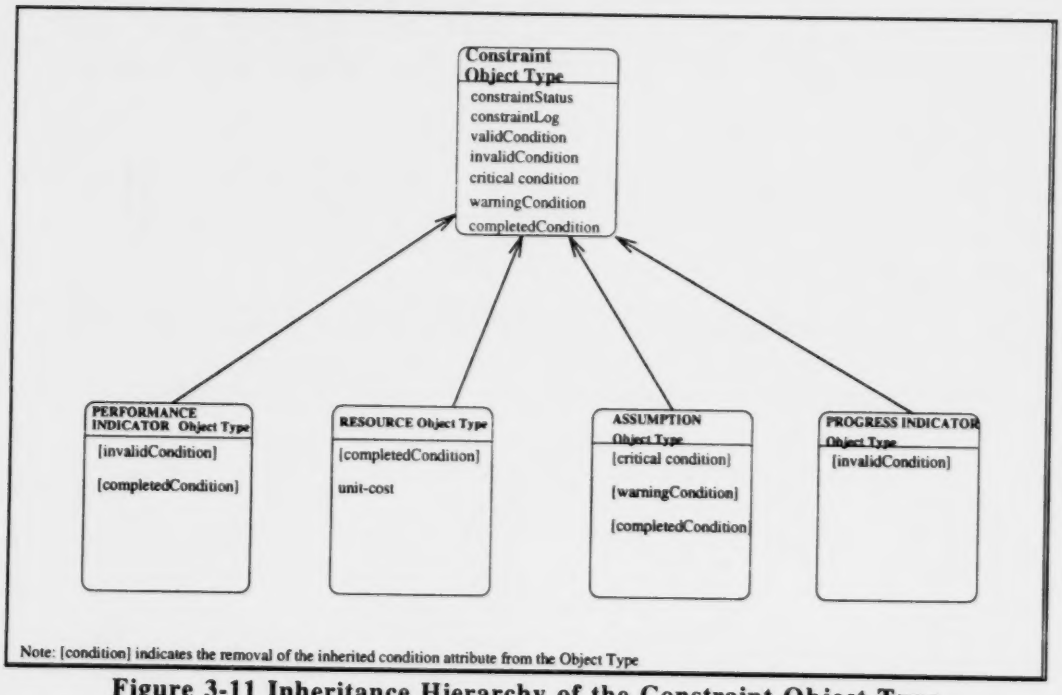

Figure 3-11 Inheritance Hierarchy of the Constraint Object Type

5. Identify the specialized Constraint Relationship Types between the specialized StrategicPlan Object Types and the appropriate specialized Constraint Object Types.

There are a total of 5 Constraint Relationship Types identified in the RSPPE process, namely, the *CSF-**is-constrained-by**-PERFORMANCE-INDICATOR*, *OBJECTIVE-**is-constrained-by**-PERFORMANCE-INDICATOR*, *OBJECTIVE-**is-constrained-by**-ASSUMPTION*, *ACTION-PLAN-**is-constrained-by**-RESOURCE*, and *ACTION-PLAN-**is-constrained-by**-PROGRESS-INDICATOR* Relationship Types.

There is a need within the *ACTION-PLAN-**is-constrained-by**-RESOURCE* Relationship Type to model the resource requirements for the action plan. The units of the resource required is therefore captured as a property of the Relationship Type and is used to calculate the cost of the action plan.

6. Identify any specialized Analyzer Object Types and Sensor Object Types and any unique attributes that they may have.

In the RSPPE Process, specialized Analyzer or Sensor Object Types are not necessary.

7. Identify any specialized Monitor Relationship Types.

There are a total of 4 specialized Monitor Relationship Types, namely, the *PERFORMANCE-INDICATOR-**is-monitored-by**-SENSOR/ANALYZER*,*ASSUMPTION-**is-monitored-by**-SENSOR/ANALYZER*, *RESOURCE-**is-monitored-by**-SENSOR/ANALYZER*, and *PROGRESS-INDICATOR-**is-monitored-by**-SENSOR/ANALYZER* Relationship Types.

The different Monitor Relationship Types differ only in the Constraint Object Type identified in the relationship. No special property has been identified for any of the Monitor Relationship Types.

8. Identify any specialized Activate and Detect Relationship Types.

In the RSPPE Process, specialized Activate and Detect Relationship Types are not necessary.

The customized RCIM is the key IT component to model the responsive strategic plan of the organization. However, because of the inherent complexity of the strategic management process, tools are required to allow the user to build and use the model. A RCIM prototype system is described in Chapter 4 to illustrate the system features required.

Chapter 4

Responsive Corporate Information System - the RCIM Prototype System

The Responsive Corporate Information System (RCIS) is a prototype system to demonstrate the feasibility of the IT support to the responsive strategic management approach. The structure and functionalities (major system capabilities) of the RCIS are described in this chapter and its operation is discussed in Chapter 5.

The implementation of the RCIS includes a customized RCIM with the necessary conceptual constructs for defining the organization's goals, objectives, alternative plans and their associated indicators and assumptions. Functionalities are also implemented to support the RSPPE Process described in Section 3.2. The system is implemented using the Xerox ParcPlace VisualWorks/Smalltalk object-oriented programming environment. Smalltalk is chosen because of its prototyping capability, its interactive and graphical interface, and its portability across multiple hardware and software platforms [Goldberg & Robson 89].

This chapter provides an end-user view of the RCIS. An overview of the structure and functionalities of the RCIS architecture is described in Section 4.1 and a brief discussion of the target users of the RCIS is described in Section 4.2.

4.1 Architecture of the Responsive Corporate Information Systems (RCIS)

The RCIS architecture, graphically illustrated in Figure 4-1, can be grouped into four separate components: the RCIS User Interface, the RCIS Subsystems, the RCIM database

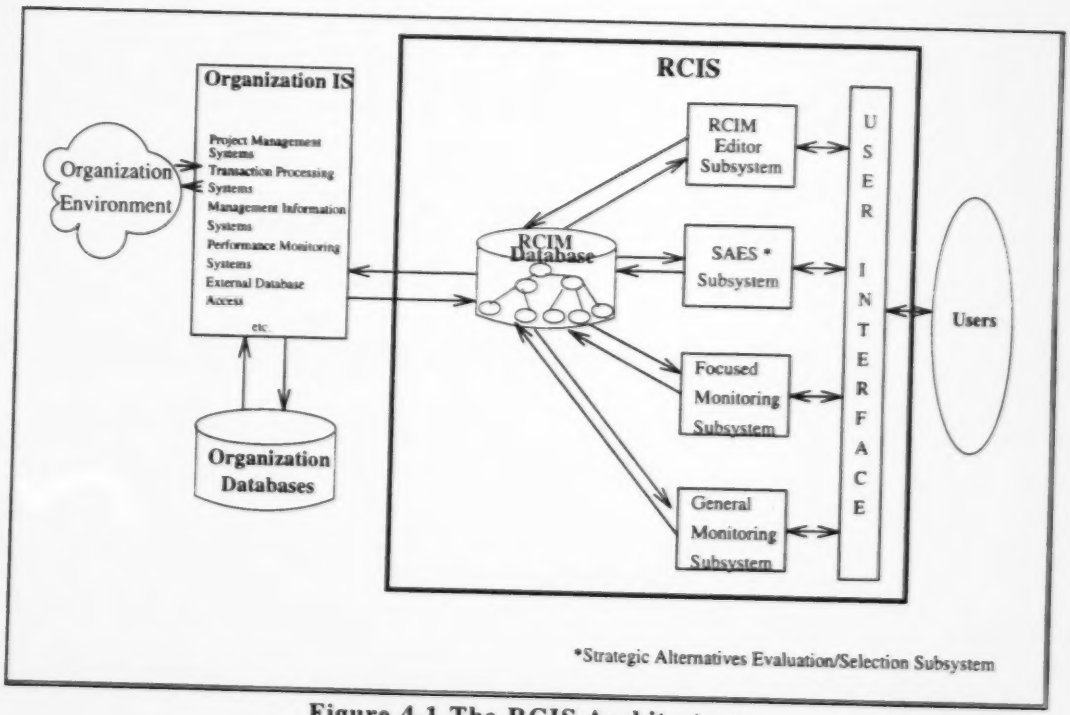

Figure 4-1 The RCIS Architecture

and the organization information systems.

4.1.1 The RCIS User Interface

The RCIS User Interface provides a common point of access to the RCIS and includes a password security subsystem for user validation. User validation serves two important purposes in the design of the RCIS. First, an organization can customize the security control to ensure that only an authorized user is allowed to use certain RCIS facilities. Examples of security include making the RCIS system administration functions accessible only to the System Administrator; making the resource commitment functions accessible only to the Comptroller of the organization, etc. Second, user validation is necessary for proper auditing of the changes to the RCIM. The design of the RCIM includes a log of all changes to the RCIM database. The date and time of the change, the user making the change, and the rationale for the change are recorded as part of the change. The user information captured during the user validation is used in decision logging.

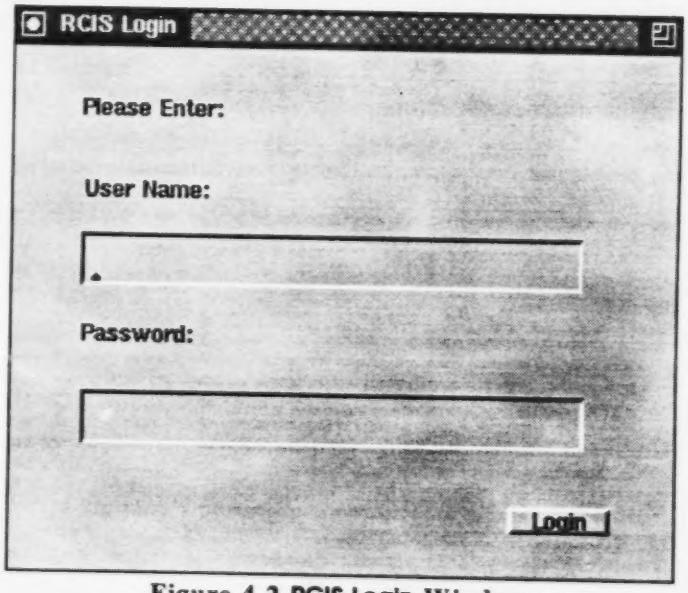

Figure 4-2 RCIS Login Window

The RCIS User Interface consists of a number of pop-up windows, with labelled input fields to prompt a user for the required input and labelled buttons for the user to request specific RCIS functions. Figure 4-2 is an example of the **RCIS Login** window. This is the entry point to the RCIS where the user enters his/her name and password to gain access to the appropriate RCIS functionalities.

Figure 4-3 is a copy of the main **RCIS** window. The main window is designed to remain active throughout the RCIS session. The menu bar at the top of the window allows the

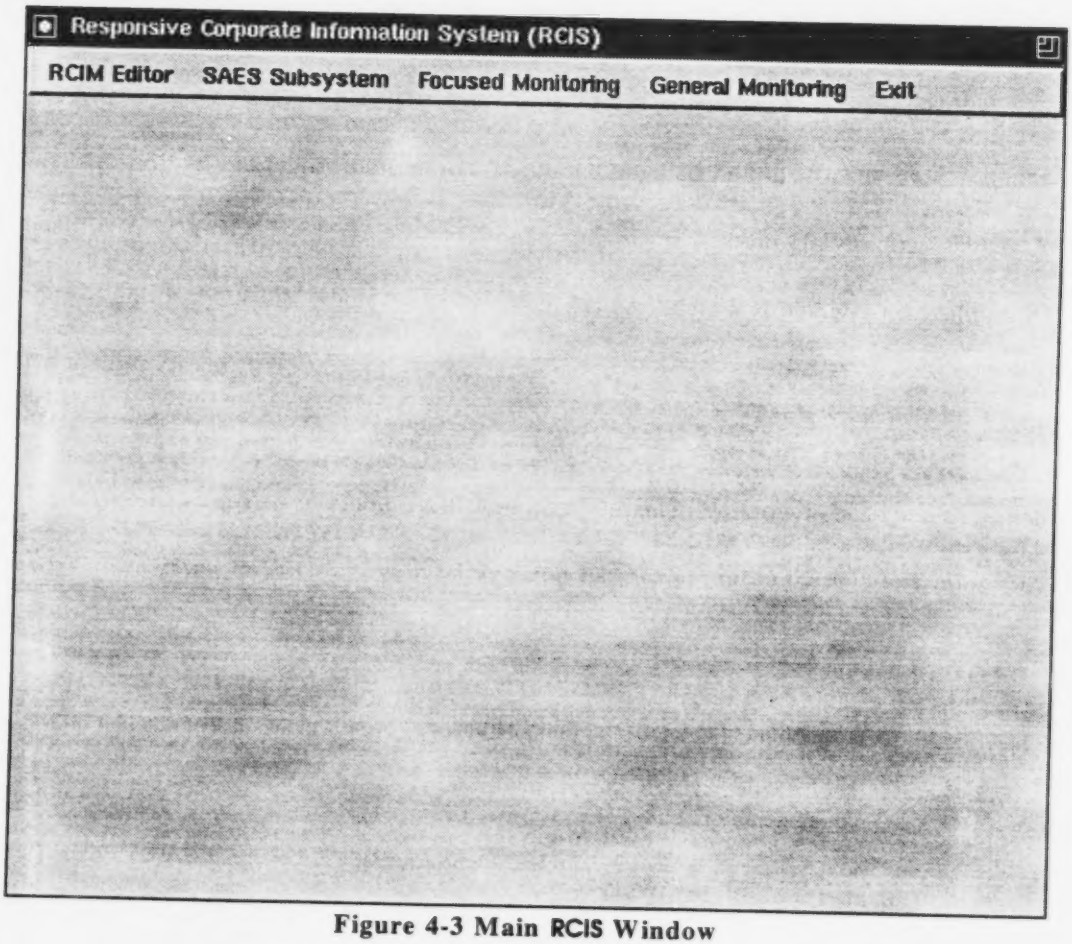

Figure 4-3 Main RCIS Window

user to choose between the different RCIS Subsystems. The **Exit** menu option in this window results in the termination of the RCIS session.

All other RCIS windows are designed to be opened via the selection of the appropriate menu options or buttons. Figure 4-4 is an example of the **Goal Input** window to illustrate the design of the windows for editing the RCIM Object Types.

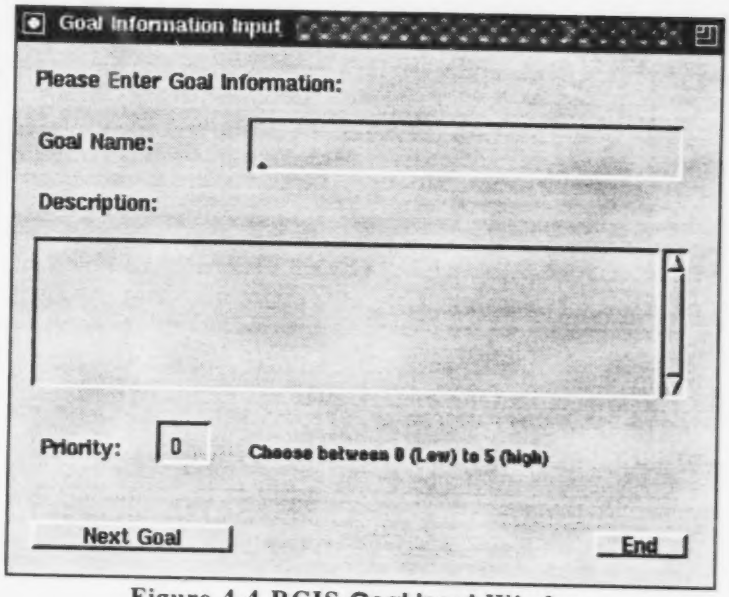

Figure 4-4 RCIS Goal Input Window

Each of these windows contains an **End** button for exiting and closing the window. Other buttons are provided as required. For example, the **Next Goal** button allows the user to end the input of one *GOAL* object and proceed to a new one. Multiple RCIS windows can be opened simultaneously, allowing flexibility in entering and verifying the RCIM data. For example, a user may discover the need to update the *latest-completion-date* of an *OBJECTIVE* object when he is entering the supporting *ACTION PLAN* object. The ability to have multiple windows opened allows the user to cross-reference the information entered.

4.1.2 The RCIS Subsystems

Four RCIS Subsystems are shown in Figure 4-1: the RCIM Editor, the SAES (Strategic Alternatives Evaluation and Selection) Subsystem, the Focused Monitoring Subsystem and the General Monitoring Subsystem. These subsystems interact with the user through the User Interface. The functions are grouped into the subsystems to allow for access control of different user groups. Each subsystem is accessed through a menu choice on the main **RCIS** window. Only menu choices appropriate to the user's security level are displayed.

The RCIM Editor

The RCIM Editor is used for entering and modifying the strategic plan into the RCIM database. There are three sub-menu options under the RCIM Editor, namely, the **Goal Setting**, **Plan Details** and **Focused Monitoring Set-Up** options. Each of the sub-menu options is further broken down into a list of sub-menu options. The **Goal Setting** sub-menu includes the functionalities for entering and modifying the goals, CSFs, performance indicators and their corresponding relationships. The **Plan Details** sub-menu includes the functionalities for entering and modifying the objectives, action plans, performance indicators, assumptions, resources, progress indicators and their relationships. The **Focused Monitoring Set-Up** sub-menu includes the functionalities for setting up the information systems resources to monitor the indicators, resources and assumptions.

The RCIM Editor is also the subsystem responsible for the maintenance of the RCIM database. It maintains the internal consistencies of the objects and relationships in the RCIM database but it does not verify the completeness of the strategic plan entered. For example, when the user specifies that an objective is decomposed into three lower level objectives, the RCIM Editor creates the appropriate *OBJECTIVE_**is_supported_by**_OBJECTIVE* Relationship Type objects to capture the relationships between the four *OBJECTIVE* objects. However, the Editor does not verify that the three lower level objectives together fully support the higher level objective. In other words, it does not verify that the sum of the *percentageContribution* attribute of the three lower level objectives is equal to 100%. This completeness verification of the responsive strategic plan is handled by the SAES Subsystem as a user-initiated function via the sub-menu option **Completeness Verification**. It is also initiated automatically by the SAES Subsystem before the selection algorithm is executed to ensure that the plan is complete before selection begins. The deference of the completeness verification allows the organization to construct the responsive strategic plan in stages.

The SAES Subsystem

The SAES subsystem is responsible for the selection of the strategic alternatives, and the commitment of resources to the selected alternatives. It is the primary tool for senior management to specify the strategic decisions, and its access is typically limited to the senior management. There are three sub-menu options under the SAES Subsystem,

namely, the **Plan Preparation**, **Plan Selection** and **Plan Commitment** options.

The **Plan Preparation** sub-menu includes the functionalities for getting the strategic plan ready for the selection process. It allows the organization to verify the "completeness" of the strategic plan, which includes ensuring that all strategic alternatives, except for the action plans, are fully supported; all strategic plan components (CSFs, objectives, and action plans) have at least one Constraint object (performance indicators, assumptions, progress indicators) associated with them to monitor their progress; and all Constraint objects have Sensor and Analyzer objects associated with them to detect and analyze their changes.

The **Plan Selection** sub-menu includes the functionalities for the organization to specify the total amount of resources available for implementing the strategic plan; for initiating the selection algorithm; and for manually selecting strategic alternatives and de-selecting them. The resource availability information is used by the selection algorithm to limit the selection of the strategic alternatives. This information must be provided prior to execution of the selection algorithm. In designing the support for the strategic decision process, it is recognized that some strategic decisions may be made as an exception to the pre-defined selection algorithm. An example is a commitment to a specific project even when a less resource intensive alternative is available. The rationale for such over-riding decisions may be based on management intuition that will only become obvious at a later time, or on highly confidential information that cannot be publicly shared. Manual

selection allows authorized users (typically the CEO or equivalents) to 'force' the selection of a specific alternative. Recording such decisions in the RCIM database allows the organization to analyze its decision making practice. For example, a high occurrence of manually selected alternatives based on intuition may reflect a highly innovative approach to accomplish a strategic objective; while a high occurrence of manually selected alternatives based on confidential rationale may reflect a highly political project.

The **Plan Commitment** sub-menu allows the user to initiate the RCIS operation to mark the currently selected strategic alternatives in the RCIM database as "committed". These "committed" alternatives are the ones that the organization will implement unless changes in environmental conditions impact the responsive strategic plan to the point where changes in the overall selection is required.

The Focused Monitoring Subsystem

The Focused Monitoring Subsystem is the subsystem responsible for environment monitoring. It interacts with the user to alert them to changes in the organization environment and prompts them for corrective actions. The sub-menu of the Focused Monitoring Subsystem includes **Plan Presentation**, **Status Reports** and **Manual Monitoring**.

The **Plan Presentation** sub-menu includes the choice of several reports. The sub-menu **All Plans** results in a report of all strategic alternatives in the overall responsive strategic plan.

The sub-menu **Selected Plan** results in a report of the selected strategic alternatives, and the sub-menu **Committed Plan** results in a report of the committed strategic alternatives.

The **Status Reports** submenu consists of a list of reports identifying recent changes in the environment according to their impact to the organization's strategic management process. Four reports are available, one for each type of change in the environment. The four types of changes are: *imminent* changes, *critical* changes, *warning*, and *notification*. Classifying the changes allows the user to respond to the changes based on their urgency.

Imminent changes are the ones that result in immediate changes in the overall strategic plan. A typical example is the invalidation of an assumption of an objective that is committed for implementation. The objective has been accepted on the assumption that a government regulatory policy is approved. Disapproval of the government policy (a change in the external environment) results in the invalidation of the assumption and a change in the status of the *OBJECTIVE* object from "feasible/committed" to "not feasible/not committed". The invalidation of the assumption and the status change of the objective take place immediately in the RCIM database. The user is advised about the *imminent* change and its impact to the overall strategic plan is outlined in the report. The user is then prompted to proceed with corrective actions such as the addition or modification of some strategic alternatives, execution of the selection algorithm to select another set of strategic alternatives, etc.

Critical changes are changes in the environment which have been identified by senior management as having critical impact to the overall strategic plan if they are not attended to promptly. In other words, these changes match the critical conditions specified in the constraints defined to monitor the progress of the strategic alternatives. An example is a critical level being reached in one of the performance indicator for an objective. This critical level may have been reached because the action plan selected to achieve this objective have not performed as expected. Management intervention may be necessary to modify the action plan to increase the resource allocation, or to replace the ineffective action plan with an alternative action plan. Such a decision making process is complicated. Complete decision rules may not exist to automate it. Users are alerted to the critical situations via the report and prompted for corrective actions. They can use the information in the RCIM database to assist them in making a more-informed decision.

Warning changes are changes that may have an impact on the overall strategic plan. These have been identified by management during the planning stage as situations that must be studied and monitored closely for further development. In other words, these changes are specified within the warning conditions of the constraints defined to monitor the progress of the strategic alternatives. An example is a delay in a milestone event in a committed action plan. Such a delay may be recoverable by the project team responsible for the action plan and may not actually impact the overall plan. However, management wants to be alerted to these situations to ensure that they do not deteriorate further. A warning may also be used to identify environmental changes that is believed intuitively

to have an effect on parts of the strategic plan but the nature and significance of the effect is not clearly understood. While management needs to be aware of the changes, corrective action may not be warranted. Specifying such changes as warning conditions allows the changes to be identified for further analysis.

Notifications are changes in the environment that are of interest to senior management. However, no action is required to deal with these changes. An example is the completion of an action plan.

The **Manual Monitoring** submenu prompts designated users to evaluate environmental conditions and enter the results in the RCIM database. This occurs when a user has been delegated the responsibility of manually evaluating certain environmental conditions. The appropriate user interface window to prompt for the entry of the information are listed as submenu choices for the designated user.

The General Monitoring Subsystem

The General Monitoring Subsystem is basically an executive information system. It enables the user to browse through the environment for any information that may be useful to the decision making process. Information identified through this random scanning of the environment can be used to enhance the RCIM and expand the focused monitoring activities of the RCIS. In essence, the General Monitoring and Focused

Monitoring Subsystems provide the two complements of environment monitoring discussed in Section 2.3. This subsystem is included in the prototype for completeness; however, its implementation is outside the scope of this dissertation.

4.1.3 The RCIM Database

The RCIM database stores and manages the RCIM objects created for the organization. In the RCIS prototype, the RCIM database is implemented using Smalltalk objects. The discussion of the Smalltalk implementation of the RCIM is included in Appendix B and is not repeated here.

4.1.4 The Organization Information Systems

The organization information systems include the transaction processing systems, management information systems, performance monitoring systems, external data base access systems, net cruising systems, project management systems and document retrieval systems that exist in the organization. Using the RCIM, specific applications within these information systems are identified as feeder systems to the RCIS. For example, if "percentage of aged receivables to overall receivables" is determined as a performance indicator of an objective, applications in an Accounts Receivable System can be identified to extract the required information at regular frequency, analyze it against expected performance level, and raise the appropriate alert in the RCIS. Similarly, a document

retrieval system, possibly implemented on multi-media databases, can be deployed to store all the detailed supporting information of the different proposals of the strategic plans. Using relationships established in the RCIM, management can access details of the original proposals to assist them in making a more informed decision.

4.2 Target Users of RCIS

The target users of the RCIS are described in this section to provide an end user view of the system usage. Table 4.1 outlines the target users of the various RCIS subsystems. Four groups of users are listed: the *senior management* (SM), the *department managers* (DM), the *information experts/data administrators* (IE/DA), and the *project managers* (PM). Usage is also distinguished between the primary and secondary users. The primary users have direct responsibility for the task; and the secondary users are typically involved in providing advice or recommendation for carrying out the task.

Senior management refers to the top level decision makers in the organization such as the presidents, vice-presidents, chief executive officers, senior directors etc. They have corporate-wide responsibilities and their decisions are business-focused instead of operation-focused. Within the context of strategic management, senior management is responsible for setting the vision, the goals and the high level objectives for the organization; for committing (authorizing) the resources to implement the strategic plan;

and for ensuring that the organization as a whole progresses towards the accomplishment of the goals and objectives. Therefore, the RCIM Editor, the SAES Subsystem and the Focused Monitoring Subsystem are designed to be used directly by senior management to perform their strategic management tasks.

	SM	DM	IE/ DA	PM
RCIM Editor				
to set goals and high level objectives	P	S	-	-
to propose strategic alternatives	S	P	-	-
to identify IS support for monitoring strategic plan	S	S	P	S
Strategic Alternatives Evaluation and Selection Subsystem				
to evaluate and select the strategic alternatives	P	-	-	-
to commit resources to the selected strategic alternatives	P	-	-	-
Focused Monitoring Subsystem				
to review change reports	P	P	S	P
to manually evaluate designated environmental conditions/progress of projects	-	-	P	P
General Monitoring Subsystem	P	P	P	P

P - identifies primary users
S - identifies secondary users

Table 4.1 Target Users of the RCIS Subsystems

Department managers refer to the middle and lower level managers directly involved in the operations of the organization. Their scope of responsibility and decisions are limited within the operation of a department or functional unit of the organization, eg. manager of the accounting department. Within the context of strategic management, department managers are responsible for proposing ways on how his/her department can contribute to the accomplishment of the organization's goals and objectives. Proposals typically include estimates of resource requirements and expected contributions to specific goals and objectives. Where appropriate, proposals may involve collaboration with other departments or units.

I*nformation experts/data administrators* refer to personnel within the organization who are knowledgeable about corporate information needs and availability. Within the context of strategic management, the information experts/data administrators are responsible for identifying the IS support to monitor the strategic alternatives. As information experts, these personnel are often delegated the responsibility to manually evaluate specific environmental conditions and to record their evaluation in the RCIM database. In essence, they provide the environmental monitoring support that cannot be automated either because the information sources cannot be electronically accessed or because the decision rules for the evaluation are not precise enough for automation.

Project managers are responsible for the detail planning and management of specific projects. Within the context of this discussion, a project is an action plan identified in the

strategic planning process. Each action plan consists of a series of steps that must be accomplished as a whole to achieve an objective. A project manager is responsible for the successful completion of the project, and keeping the organization up-to-date with the project progress.

Several points are noted with respect to Table 4.1. First, the RCIS is designed with the senior management as the primary users. However, some usage is extended to the rest of the organization in order that the more detailed tasks can be delegated, eg. the identification of the IS support for monitoring the strategic plan is delegated to the information experts or data administrators. Usage is also extended to enable the department managers to directly input and review strategic alternatives to meet the goals and objectives, allowing the organization to implement a more participatory management approach. Such an approach provides a more conducive environment for proposal submission. As indicated in Chapter 2, the responsiveness of the RCIS is directly related to the number of alternatives proposed. A participatory management approach that encourages the organization to generate more strategic alternatives is therefore desirable.

Second, the current design ignores the complications of conflicting goals and critical success factors which may require negotiations among senior managers for resolution. Such negotiations may be manually carried out or they may be supported electronically by Group Decision Support Systems (GDSS) [Nunamaker et al 89]. Support to these negotiation is outside the scope of this thesis. Conceptually, GDSS may be viewed as a

front end processor that filters out the conflicting input to the RCIS Editor. In essence, goals and critical success factors entered into the RCIS are considered to be a cohesive and non-conflicting set.

Third, access to the SAES is restricted to the senior management since they are the only ones with the authority to select and commit resources to the implementation of the strategic alternatives. However, the RCIS allows all strategic alternatives to be selected based on common selection criteria consisting of the cost (resource estimates) and benefits (contribution towards the stated goals) of all viable alternatives. The ability to review and critique all strategic alternatives, assumptions, criteria for selections, and subsequent selection allows the organization to implement an open and team-based management approach.

Fourth, the open access to the Focused Monitoring Subsystem and General Monitoring Subsystem allows the environment monitoring activities to be delegated throughout the organization. In a dynamic environment, an organization-wide monitoring effort helps to promote a more responsive management approach.

Chapter 5

Operation of the RCIS using the ITRI as an Example

During phase three of this thesis research, a responsive strategic plan is constructed from an existing strategic plan of an organization and a model of the plan is instantiated using the RCIS Prototype. This modelling exercise provides insight into the development process of a responsive strategic plan and the capabilities and limitations of the RCIM. Several changes commonly found in an organization environment are simulated using the model as an example. These simulations provide the opportunities to visualize the interaction between the RCIS and its target users so that tools and methods can be created with the goal of further enhancing user interaction.

The strategic plan developed for the Information Technology Research Institute (ITRI) in 1992 [ITRI 92] is used as an example throughout the exercise. The choice of the example strategic plan was based on several considerations. First, the strategic plan must consist of basic strategic plan components such as organization goals, action plans, performance indicators, and assumptions. Ideally, the plan should contain real data to allow the exercise to be related to real-life situations. Since the exercise requires the modification of the ITRI strategic plan to a responsive strategic plan, background information of the

planning process must be available to allow strategic alternatives to be constructed for the responsive strategic plan. Second, to allow for a manageable prototype system and study, the strategic plan must not be too large and complex. Third, examples of changes and corresponding corrective actions must be available so that the prototype system can be used to simulate the dynamic situations. The ITRI and the rationale behind its selection is briefly introduced in Section 5.1. Details of the strategic plan are included in Appendix A for reference.

An overview of the Responsive Strategic Planning/Plan Execution (RSPPE) Process is discussed in Section 5.2. The development of the ITRI responsive strategic plan during the goal setting and strategic planning phase are discussed in Section 5.3 and 5.4, respectively. The simulation of the changes is discussed as several scenarios in Section 5.5. Since the RCIM and RCIS Prototype are customized for the RSPPE process, the discussion reflects the terminology used in the RSPPE process. However, the scenarios are generic to most strategic management process.

5.1 Brief Introduction of the ITRI

The Information Technology Research Institute (ITRI) was initiated by the Department of Computing Science, University of Alberta in an effort to actively pursue collaborative research and improve external liaison with industry and other University departments. A

strategic plan and a business plan [ITRI 92] for the Institute were developed in 1992. The plans outline information about the organization goals, CSFs, performance indicators and action plans. Some of the assumptions made during the planning phase were documented. The plans were developed with the support of the Research Planning and External Relations Committee of the Department of Computing Science. They were reviewed and approved by the Executive Committee of the Department, the Department Council and the Industrial Advisory Committee of the Department. Since 1992, several key assumptions in the strategic plan have been invalidated by critical changes in the economy. Consequently, the strategic plan was not implemented in full and the Institute did not get established. However, some action plans were implemented as separate initiatives of the Department. Others were postponed or modified based on new assumptions about the organization environment.

In considering the use of the ITRI strategic plan as an example in this research, it is recognized that the original plan contains the basic strategic plan components such as organization goals, action plans and assumptions, etc. The development and approval process for the original plan attests to its real-life content. In addition, the researcher is familiar with the background of the ITRI and the strategic planning process. This familiarity facilitates the construction of the strategic alternatives retroactively to convert the ITRI strategic plan into a responsive strategic plan. Lastly, the critical changes experienced by the ITRI provided the basis for constructing the change scenarios.

The original ITRI strategic plan contains five goal statements and ten critical success factors. Thirty-two performance indicators and their corresponding 5-year targets were also identified. To convert the original ITRI strategic plan to a responsive strategic plan, strategic alternatives consisting of objectives and action plans were constructed for the critical success factors. Fifty one strategic alternatives (twenty one objectives and thirty action plans) were constructed to support the critical success factor **CSF1**. Since the purpose of this phase of research is to illustrate how the RCIM can be used to support the responsive strategic management process and to study the capabilities and limitations of the RCIM, the construction of the strategic alternatives for all the CSFs in the strategic plan is not deemed to be necessary. Only the strategic alternatives for a small subset of the CSFs are constructed.

The critical changes that impacted the key assumptions of the original strategic plans form the basis for constructing some of the change scenarios. In addition, new goals, critical success factors, objectives, etc. were discovered in the process of constructing the responsive strategic plan. In real-life, the addition of new strategic plan components throughout the strategic management process is quite common. Change scenarios are therefore constructed to provide insights into the RCIM support in these situations.

5.2 Overview of the Responsive Strategic Planning/Plan Execution (RSPPE) Process

In this section, an overview of the responsive strategic management process is first discussed to illustrate the detailed processes that are involved, the conditions under which each process is initiated, the users involved in the processes, and the information that is required or generated by the processes.

An extended form of a data flow diagram (DFD) is used as to illustrate the overview of the RSPPE process graphically. DFD was first introduced and popularized in the late 1970 by Yourdon, Constantine, and DeMarco [Yourdon & Constantine 78, DeMarco 78]. The original notations allow the users to describe the flow of data (input and output) through the different processes (units of computation or operations) of a software system. The notations were later extended to incorporate the concept of event in order to identify the specific conditions under which process invocation occur [McMenamin & Palmer 84, Ward & Mellor 85, Hatley & Pirbhani 87]. The notations used in this dissertation are based on the extended DFD notations. Other notations are included to represent the different types of users and data sources involved in the processes. All DFD notations used are summarized in Figure 5-1.

Figure 5-2 is a graphical overview of the RSPPE process. Four processes are identified, namely, the *Set Goal, Enter Strategic Proposal, Select Strategic Proposal* and *Monitor Environment* processes. They are shown within the strategic management phases in which they typically occur, eg. the *Set Goal* process is shown within the goal setting phase.

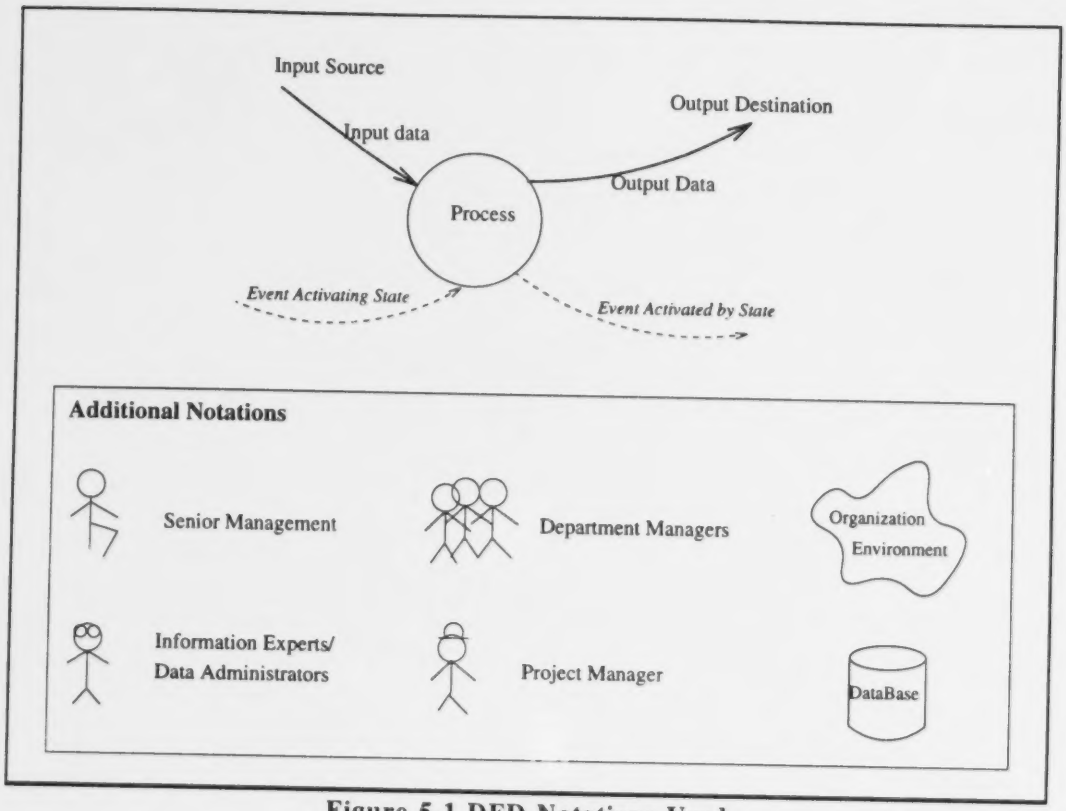

Figure 5-1 DFD Notations Used

Several points are worth noting from this overview. First, there is significant overlap between the management control phase and the other two phases. The overlap illustrates a fundamental concept of the responsive strategic management process, i.e. the continuation of the strategic planning activities even after a set of strategic alternatives has been selected for implementation. The commitment to constantly explore the opportunities to improve on the overall strategic plan and to evaluate and update the viability of the strategic alternatives is the key to the responsiveness of this strategic management approach.

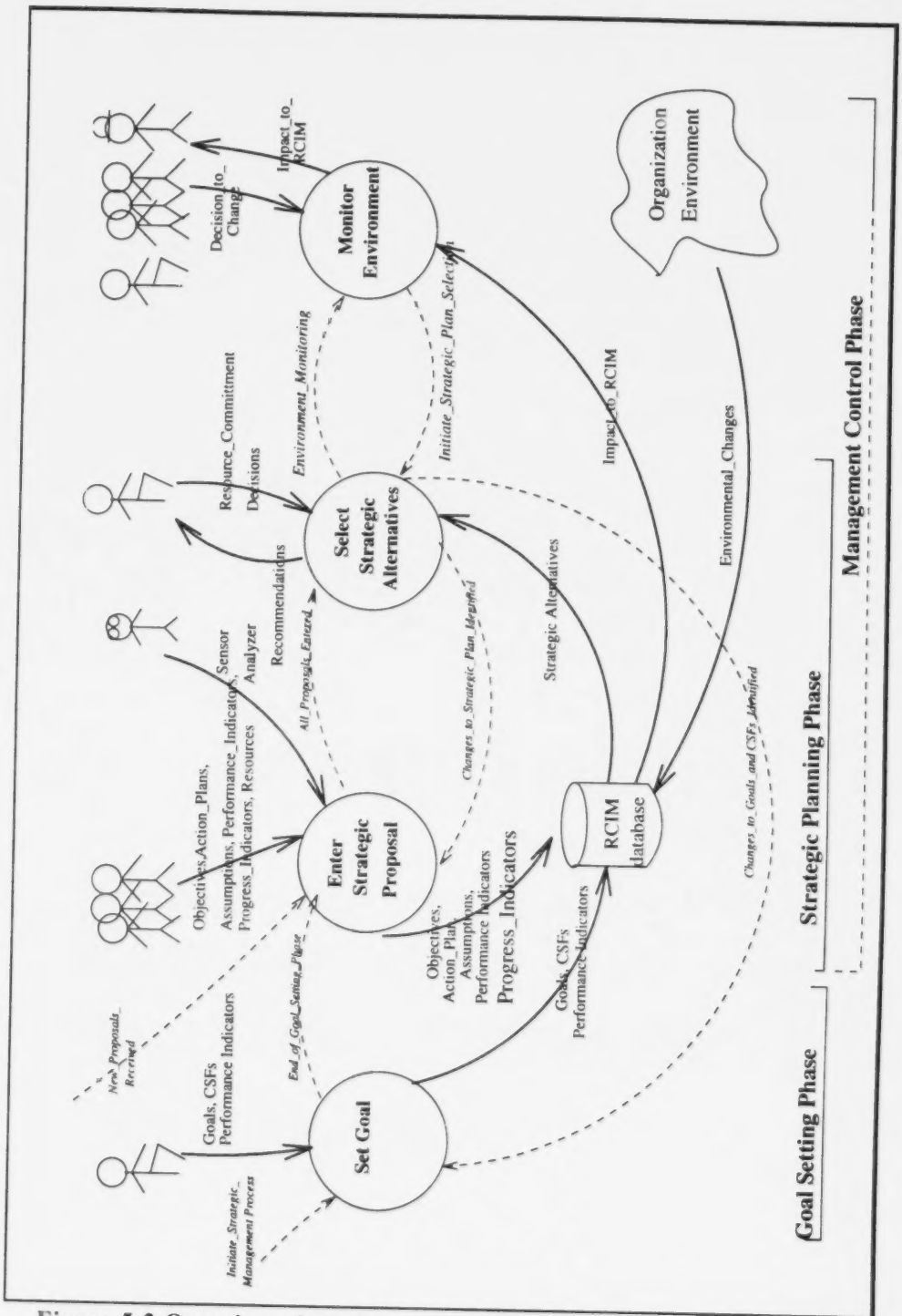

Figure 5-2 Overview of the Responsive Strategic Management Process

Second, the *Set Goal* process and the *Enter Strategic Proposal* process are primarily data capture processes. Details about goals, strategic alternatives, monitoring requirements are captured and entered into the RCIM database. The information is then used by the organization within the *Select Strategic Alternatives* and *Monitor Environment* process to respond to changes in the environmental conditions.

Third, the *Select Strategic Alternatives* process is an iterative process during which senior management reviews the overall strategic plan and select a set of alternatives for implementation. It allows senior management to do what-if evaluation of changes to the strategic plan before final commitment to the selected plans are made.

Fourth, the *Monitor Environment* process includes all detailed processes that occur during the management control phase. Changes in the environment effect changes in the RCIM database and alert management to appropriate corrective actions. These actions may involve addition, modification or a different selection of the strategic alternatives in the RCIM database. In essence, the organization reviews and re-does parts of its strategic planning process in order to keep its strategic plan up-to-date with the environment.

In the remainder of the chapter, the four processes are described in more detail. The first three processes are discussed using the ITRI as an example to illustrate the development of a responsive strategic plan. The *Monitor Environment* process is dynamic in nature and is discussed using several change scenarios.

5.3 Using the RCIS during the Goal Setting Phase

During the goal setting phase, extensive research of market trends, organization strengths and weaknesses, and competitors' threat are carried out in order to establish a set of challenging yet realistic goals for the organization. The information required to support the processes in this phase is broad-scoped and difficult to pre-plan [Rockart 79]. However, the subset of information identified as a result of these processes is crucial to the remainder of the strategic management process. For the RSPPE process, this information includes details about the goals, critical success factors, performance indicators and targets. The emphasis of the RCIM support for the goal setting phase is in capturing the set of information that is relevant to support the processes in the next two phases.

In this section, the detailed processes for entering the goals and critical success factors (CSFs) are described. In addition, the process of identifying the performance indicators and setting up the support to automate the monitoring of the progress within the critical success factors is discussed. The capabilities and limitations of the RCIM in supporting the detailed processes are highlighted where appropriate.

Entering a Goal

Figure 5-3 illustrates how one of the ITRI goal, **Goal1**, is entered into the RCIM database

using the **Goal Input** window of the RCIS Prototype. A list of the ITRI goals can be found in Table A-1. The unique identifier **Goal1**, the goal statement, and the priority are entered into the **Goal Name**, **Description** and **Priority** fields, respectively.

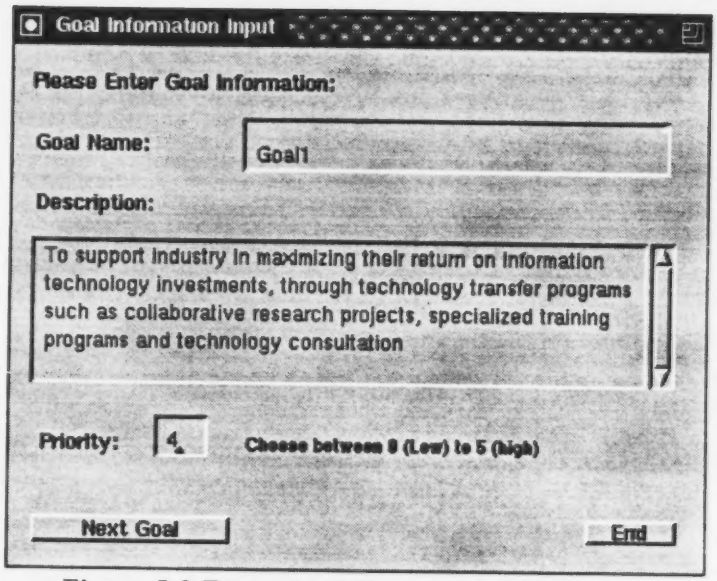
Goal Information Input
Please Enter Goal Information:
Goal Name:
Goal1
Description:
To support industry in maximizing their return on information technology investments, through technology transfer programs such as collaborative research projects, specialized training programs and technology consultation
Priority:
4
Choose between 0 (Low) to 5 (high)
Next Goal
End

Figure 5-3 Example of Entering an ITRI Goal

It is important to realize that there are two different types of data involved in the description of a goal, namely, definitional data and comparative data. Definitional data refers to data that defines the goal, eg. the name (ie. the unique identifier) and the description (ie. the goal statement) of the goal. This data is relatively static and does not change with the addition of other goals. Comparative data, on the other hand, refers to data such as the priority of a goal which identifies its relative importance with respect to other goals. This data is often referred to as soft data because it is based on subjective judgement. In general, comparative data is changed more frequently. The addition of a new goal often requires the re-assessment of the priority of all goals. Subjective data is also prone to negotiation and compromise within a group decision situation. The input of definitional data is straightforward and can be accomplished with minimum editing. The

Goal Input window of the RCIM Editor is an adequate tool for entering the definitional data. However, the input of comparative data such as the priority of goals requires a different type of tool.

Prioritization of the goals often represents subjective assessment of their relative importance by the senior management. While it is usually possible to compare the relative importance of two goals, it is much more difficult to assign the relative importance of multiple goals. Quantitative methods such as the analytic hierarchy process (AHP) [Saaty 80] are available to assist the senior management to derive the relative importance of multiple goals [Anderson et al 92]. Using the AHP, the decision maker is prompted to input successively the pairwise comparison value of each pair of goals. The pairwise comparison values of all the pairs are then synthesized to compute a set of values that represent the relative importance of the goals. The computed values are entered into the RCIM database. In essence, the input to the RCIM database is quite different from the primary input provided by the user.

Comparative data is common in unstructured and semi-structured decision making processes. In the RSPPE process, percentage contribution is a property of all the Support Relationship Types in the RCIM. The user has to identify the percentage contribution of each CSF supporting a goal, each objective supporting a CSF, each objective supporting a higher level objective, and each action plan supporting an objective. Percentage contribution of a CSF represents its relative importance to the successful accomplishment

of the supported goal. Table A-2 (in Appendix A) lists all of the CSFs identified in the ITRI Business Plan and Table A-3 (in Appendix A) lists the percentage contribution of the CSFs. Consider the CSFs supporting **Goal1**. The allocation of a percentage contribution of **0.45** to **CSF1** indicates that the success or failure of this CSF can significantly impact the organization's ability to accomplish **Goal1**. In other words, if "**collaborative research with industry**" (**CSF1**) fails, it is unlikely that the ITRI will be able to successfully achieve the goal of "**Supporting industry in maximizing their return on information technology investments**" (**Goal1**). The allocation of a percentage contribution of **0.05** to **CSF2**, **CSF3**, **CSF8**, **CSF9** and **CSF10** respectively indicates that each of these CSFs contributes to the successful accomplishment of **Goal1** but the individual contribution is not too significant. Failure of any one of these CSFs will not result in a significant impact to the organization's successful accomplishment of **Goal1**.

The high proportion of comparative data among the RCIM input data means that methods like the AHP are needed in more areas of the system. The incorporation of tools supporting these quantitative methods requires the retention of the primary user input to avoid re-entry of the input data when changes are made to the set of goals. For example, if a new goal is discovered, senior management should be expected to enter only the pairwise comparison values of the new goal with each of the existing goals. The current design of the RCIM does not provide for the retention of tool-specific primary user input. The choice of tools used in a strategic management process depends on the organization's culture and practice. To avoid over complicating the RCIM customization process, it is

desirable that the interface between the tools and the RCIM be designed such that the tool-specific user input is stored separately from the RCIM database. The issues of tool integration are not addressed within this research. Further research in this area is required.

Entering a CSF and its Performance Indicators

Critical success factors represent the key areas which, if results are satisfactory, ensure successful competitive performance for the organization. Performance indicators have long been used by organizations to monitor its business performance [Elofson & Konsynski 91]. These indicators form the basis of the perception plan for the critical success factors and allow the organization to detect problems in its critical areas. Table A-5 (in Appendix A) contains a list of the performance indicators for all CSFs and their 5-year targets respectively. Since each CSF can be monitored by more than one performance indicator, and each performance indicator can monitor more than one CSF, the n x m relationships between the performance indicators and the CSFs are shown in the form of a matrix in Table A-5 (in Appendix A).

Figure 5-4 illustrates how the critical success factor **CSF1** can be entered. The **CSF Information Input** window of the RCIM Editor can be used to enter the CSF data directly into the RCIM database. However, in identifying the performance indicators to monitor the critical success factors, the organization must also determine specific targets that must be met and the consequences of not meeting these targets. This information is entered as

a set of conditions that must be closely monitored. Figure 5-5 illustrates an example of the warning and critical conditions entered for **Perf1** using the **Performance Indicator Information Input** window in the RCIM Editor.

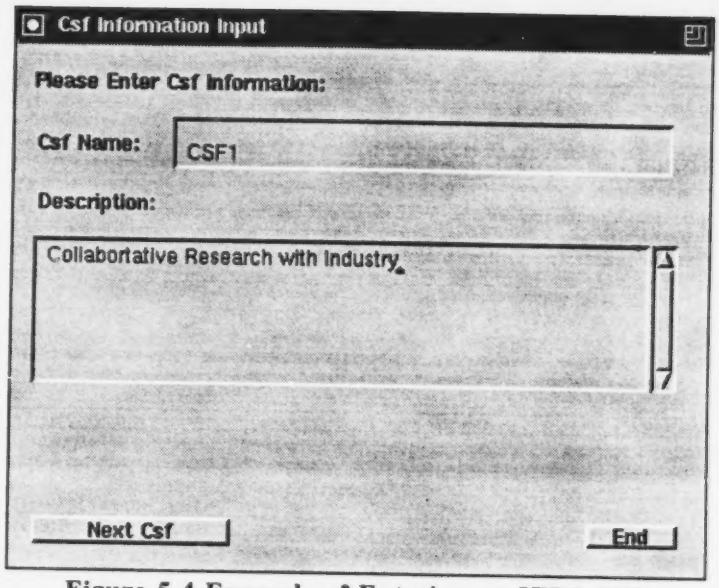

Figure 5-4 Example of Entering an ITRI CSF

In the five-year program budget of the ITRI, the targets set for the performance indicator **Perf1** include a gross revenue of $500,000 during the third year of the ITRI's operation and a gross revenue of $1 million each during the fourth and fifth year. If the Collaborative Research Program is to be successful, the YTD (Year-to-Date) Actual Revenue generated from the program should be greater than or equal to the YTD Projected Revenue at that time. If this condition is not met, management needs to be warned about the potential financial loss. This need is input into the **Warning Conditions** field of the **Performance Indicator Information Input** window. On the other hand, if the YTD Actual Revenue is less than 75% of the YTD Projected Revenue, the organization may be in serious risk of not meeting its performance target and management must be alerted to the situation so that quick action can be devised to correct the situation. This monitoring need is specified in

the **Critical Conditions** field for **Perf1**.

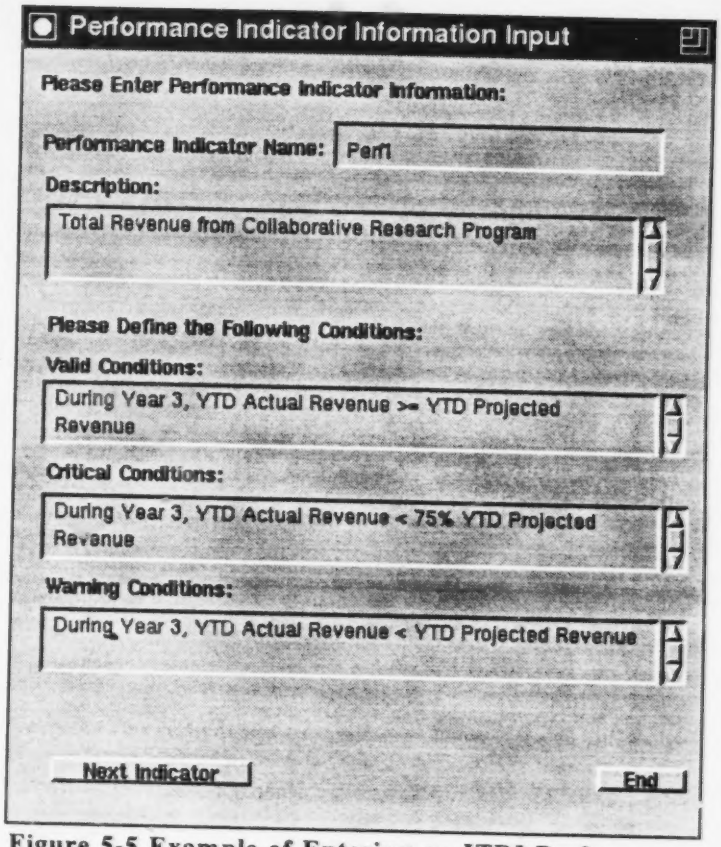
Performance Indicator Information Input
Please Enter Performance Indicator Information:
Performance Indicator Name: Perf1
Description:
Total Revenue from Collaborative Research Program
Please Define the Following Conditions:
Valid Conditions:
During Year 3, YTD Actual Revenue >= YTD Projected Revenue
Critical Conditions:
During Year 3, YTD Actual Revenue < 75% YTD Projected Revenue
Warning Conditions:
During Year 3, YTD Actual Revenue < YTD Projected Revenue
Next Indicator
End

Figure 5-5 Example of Entering an ITRI Performance Indicator

The data entered in the **Warning Conditions** and **Critical Conditions** fields are used as guidelines by the information experts or data administrator to set up the appropriate focused monitoring application programs (the set up process is discussed in more detail in the next sub-section). The **Warning Conditions** and **Critical Conditions** fields are currently designed to allow senior management to express their monitoring requirements as free-form text entry. Further research is necessary to investigate if tools can be constructed to assist senior management in specifying precise rules for the conditions. Such tools can lead to automated generation of the monitoring applications, further improving the effectiveness of the RCIM support.

Constructing the Focused Monitoring Support for a Performance Indicator

Based on the warning and critical conditions specified by senior management, the information experts and data administrators can construct the *SENSOR* and *ANALYZER* objects and initiate the focused monitoring support for the performance indicator. Through the organization's information model, the data element **YTD Actual Revenue** is located and the application program for accessing the data element **YTD Actual Revenue** is identified. The appropriate linkages can be set up via the RCIM Editor. Figure 5-6 illustrates the input for constructing a *SENSOR* object, **S-Perf1**, for the performance indicator **Perf1**.

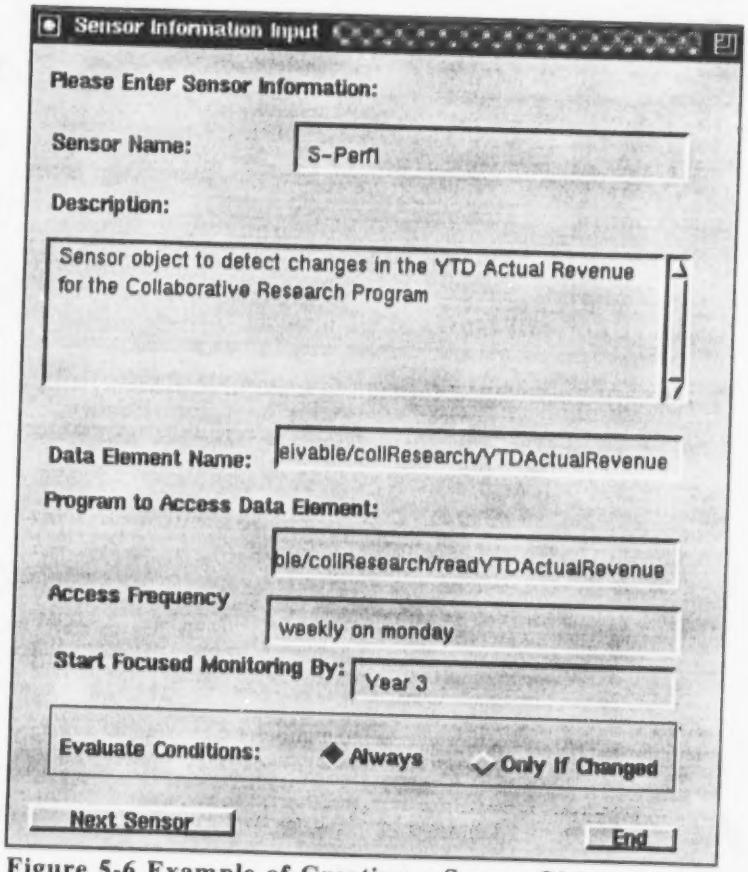

Figure 5-6 Example of Creating a Sensor Object for the Performance Indicator Perf1

The specification will result in the weekly execution of the program identified in the **Program to Access data Element** field as **accountsReceivable/collResearch/readYTDActualRevenue** to retrieve the value of the data element **YTD Actual Revenue** of the Collaborative Program. In this

particular example, the YTD actual revenue needs to be evaluated against the YTD projected revenue whether or not there is a change in value. Therefore, the **Evaluate Condition: Always** button is selected. This results in a message being sent to the associated *ANALYZER* object, **A-Perf1**, to execute the evaluation program weekly.

The process to set up the *ANALYZER* object is relatively straight forward if an application program to perform the evaluation of the required conditions exists in the organization's information systems. Figure 5-7 illustrates the input for constructing an *ANALYZER* object, **A-Perf1**, for the performance indicator **Perf1**. By selecting the **Evaluate Method: Automated** button, the user specifies that an application program exist to analyze the conditions. The name of the application program is entered in the **Analyzer Program Name** field. The specified program is executed whenever the *ANALYZER* object **A-Perf1**

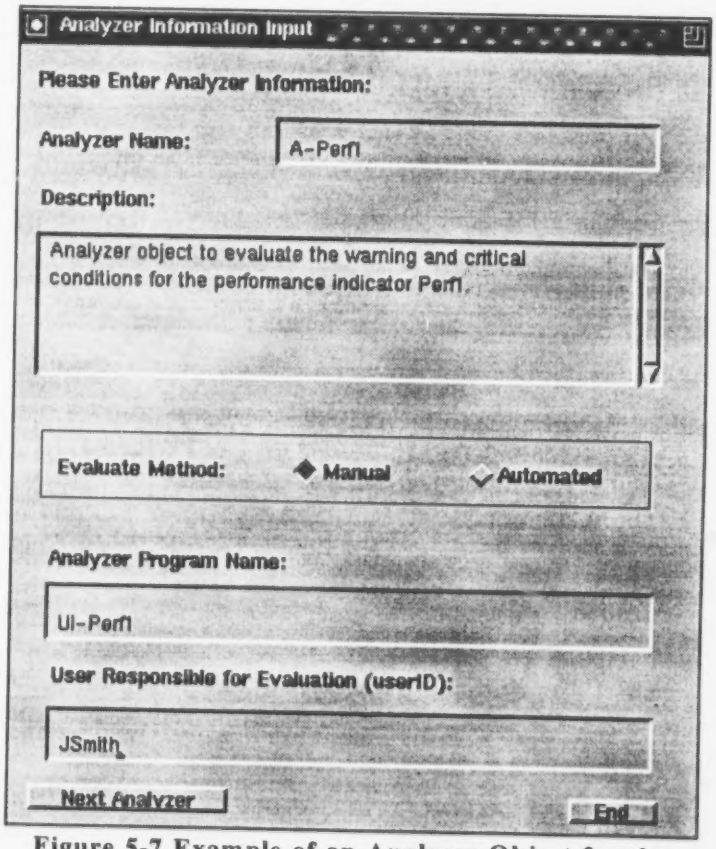

Figure 5-7 Example of an Analyzer Object for the Performance Indicator Perf1

receives the message from the *SENSOR* object **S-Perf1**. Based on the condition returned from the application program, a message is sent by the *ANALYZER* object to the *PERFORMANCE INDICATOR* object **Perf1** to set the *constraintStatus* to the appropriate value.

However, if an application program does not exist, the user can select the **Evaluate Method: Manual** button (Figure 5-7) and identify the userID **JSmith** in the **User Responsible for Evaluation** field to delegate the responsibility for the manual evaluation of the performance indicator to the user. An **Analyzer User Interface** window, **UI-Perf1**, is constructed and linked to this *ANALYZER* object. Figure 5-8 is an example of the Analyzer User Interface **UI-Perf1**. In the example given, the user with the userID **JSmith** is prompted to manually evaluate the conditions specified in the

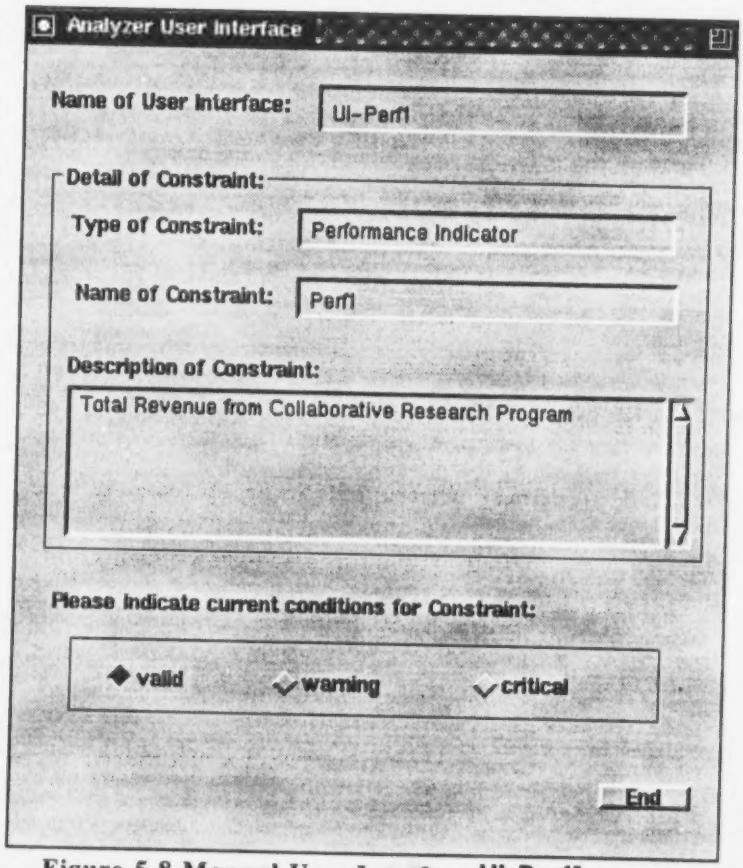

Figure 5-8 Manual User Interface UI-Perf1 for the Performance Indicator Perf1

Performance Indicator **Perf1** and enter the appropriate condition through the interface whenever the *ANALYZER* object is executed. The condition entered by the user will result in an appropriate message being sent by the *ANALYZER* object to the *PERFORMANCE INDICATOR* object **Perf1** to set the *constraintStatus*.

End of Goal-Setting Phase

After the initial set of goals, CSFs and performance indicators are entered, the information is communicated to the rest of the organization in order to motivate commitment towards accomplishing the set of goals. Feedbacks from the organization is incorporated into the RCIM database. The process is iterative, converging to a set of goals that is "bought-in" and committed to by the organization. The importance of well-developed and well-communicated organization goals to the success of the organization has been recognized in management science [Barney & Griffin 92]. Although the RCIS does not directly support the development of the strategic goals, it can be instrumental in facilitating the communication of the goals to the rest of the organization.

5.4 Using the RCIS during the Strategic Planning Phase

During the strategic planning phase, the organization is invited to submit proposals consisting of strategies and plans to accomplish the targets that are set. To support

responsive strategic management, it is important that the organization applies the partial planning strategy discussed in Section 2.2 to the development of the proposals. In other words, the proposals should be formatted as series of "what-to-do's" in order to accomplish the given goals (objectives) instead of the "how-to-do's" (action plans). The organization is also encouraged to explore multiple alternatives. The goals and CSFs that the proposal is expected to accomplish must be clearly identified and the identification of the specific action plans must be deferred as much as possible.

In this section, the *Enter Strategic Alternatives* process is discussed in two parts. The first part describes how a proposal consisting of a number of strategic alternatives can be entered in the database. The second part discusses how the resource requirements of an action plan can be entered. Then the *Select Strategic Alternatives* process is discussed in detail.

Entering a proposal consisting of a number of strategic alternatives into the RCI M database

Figure 5-9 is a graphical view of a strategic proposal designed to accomplish the critical success factor **CSF1** ("**Collaborative Research Program**") in the ITRI Strategic Plan. Detailed information about the objectives and action plans in this strategic proposal is listed in Table A-7 and A-8 in Appendix A. This proposal is constructed retroactively using information from the ITRI Strategic Plan.

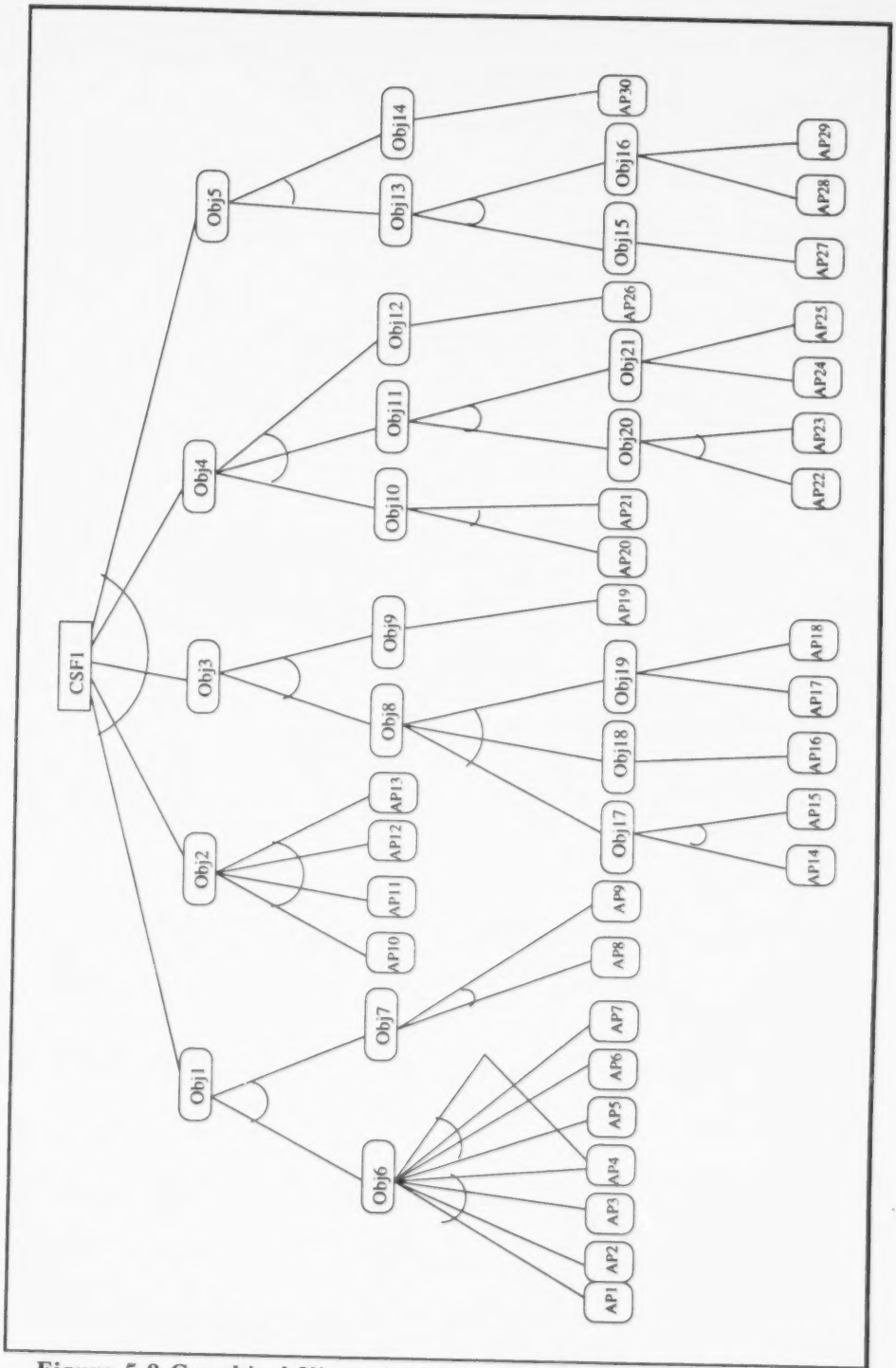

Figure 5-9 Graphical View of the Strategic Proposal to accomplish CSF1

If a proposal has been decomposed in detail to a set of objectives and action plans as outlined in Figure 5-9, it is a simple process to enter it into the RCIM database. In essence, the strategic alternatives are developed "offline" and entered into the database.

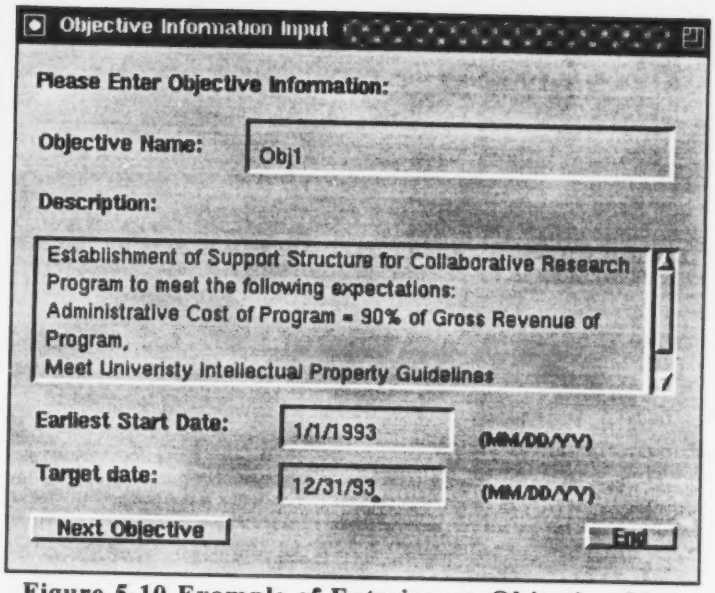

Figure 5-10 Example of Entering an Objective Obj1

Figure 5-10 and Figure 5-11 are examples illustrating how an objective **Obj1** and its relationship to the CSF **CSF1** are entered. Since the emphasis of this research is in the interactive support during the management control phase, the current RCIS Prototype is designed to support the entry of the strategic alternatives

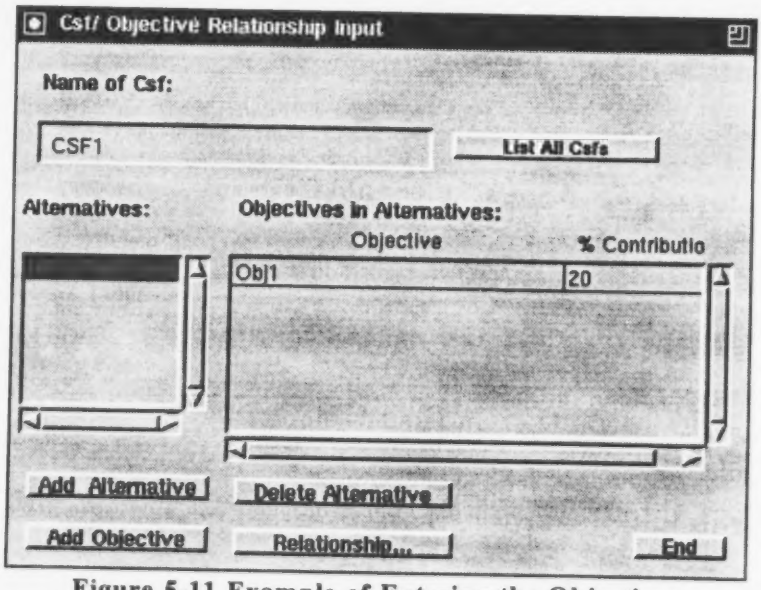

Figure 5-11 Example of Entering the Objectives supporting a CSF

that have been developed "offline". Detail information about each objective and action plan can be entered using the **Objective Information Input** (Figure 5-10) and **Action Plan Information Input** (Figure 5-12) windows of the RCIM Editor. The relationship between a *CSF* object and its supporting *OBJECTIVE* objects; a higher level *OBJECTIVE* object and its supporting OBJECTIVE objects; and an OBJECTIVE object and its supporting *ACTION PLAN* objects can be entered into the database using the **CSF/Objective**, **Objective/Objective**, and **Objective/Action Plan Relationship Input** windows.

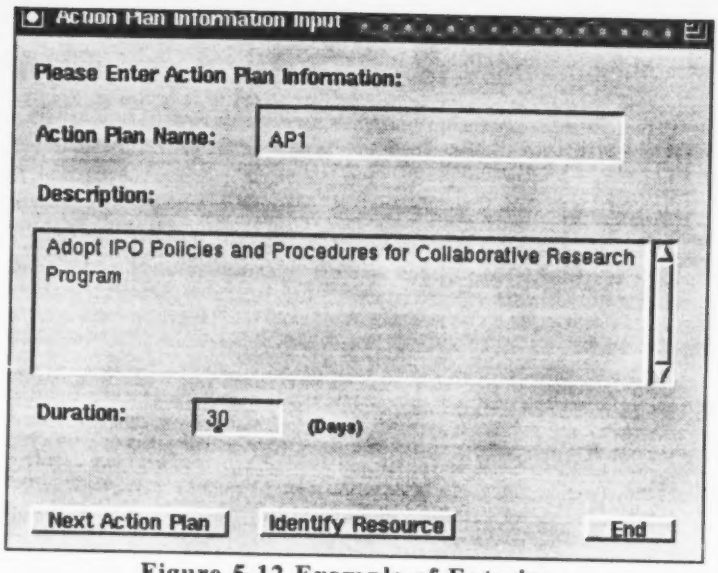

Figure 5-12 Example of Entering an Action Plan

The assumptions and performance indictors for each objective, the resource requirements and progress indicators for each action plan, and their respective focused monitoring support can be constructed using similar processes as those described for the CSF performance indicators in Section 5.3.

For RCIS to be effective, however, tools are needed to assist the organization in constructing the proposal interactively. An example may include a consistency tool to

verify that the targets for a performance indicator of a lower level objective do not conflict with the targets of the higher level objective it supports. More importantly, there is a need for interactive tools to guide the user through the responsive planning process. These tools are designed to enforce the responsive strategic planning concepts such as the focus on defining objectives instead of action plans throughout the proposal development; the emphasis on identifying the performance indicators and assumptions to support the focused monitoring activities; etc. Based on the discussion in Section 2.2, these concepts are crucial to the responsiveness of an evolving strategic plan. However, they represent a shift from traditional strategic planning approach. Without assistance, the user may continue to develop proposals that consist of series of detailed action plans with few alternatives being explored. The responsiveness of the RCIM support will be limited by the lack of alternatives when the organization has to deal with critical changes.

To assist the user in focusing on objectives, it is important to recognize the characteristics of an objective versus an action plan. Table 5-1 compares their characteristics.

Characteristics	Objective	Action Plan
Focus of the Description	Short term target	Unit of work
Focus of the Time Frame	Milestone in accomplishing target	Time required to complete action
Focus on Method Used	Not method specific	Must be method specific
Focus on Resource Requirement	Not resource specific	Resource requirements identified

Table 5-1 Characteristics of an Objective versus an Action Plan

Based on these characteristics, the following guidelines can be used to decompose an objective into a series of supporting objectives:

1. Identify a series of short term targets which together will result in the accomplishment of the given objective.

2. Identify the milestone dates for the respective short term targets.

3. Avoid restricting the method used in accomplishing the short term targets.

4. Avoid restricting the resource to be used in accomplishing the short term targets.

If the decomposition of an objective results in a series of short term targets that are method-specific and resource-specific, it is likely that the decomposition is resulting in a set of action plans being identified. Interactive tools that prompt the user to follow the above guidelines in developing the strategic proposal are highly desirable. Further research in the development of such tools is necessary.

Entering Resource Requirements of an Action Plan

To specify an action plan as a strategic alternative in the organization's responsive strategic plan, the **Action Plan Input** window is used to enter the name, description and duration of the action plan. The **Action Plan/Resource Relationship Input** window is then used to enter the resource requirements of the action plan. Figure 5-12 and Figure 5-13 are examples of the input for creating the action plan **AP1** in the ITRI Strategic Plan and its resource requirements. Three *ACTION-PLAN-**is-constrained-by**-RESOURCE* Relationship Type objects are created by the RCIM Editor linking the *ACTION PLAN*

object **AP1** with the *RESOURCE* objects **res1, res2, and res3**.

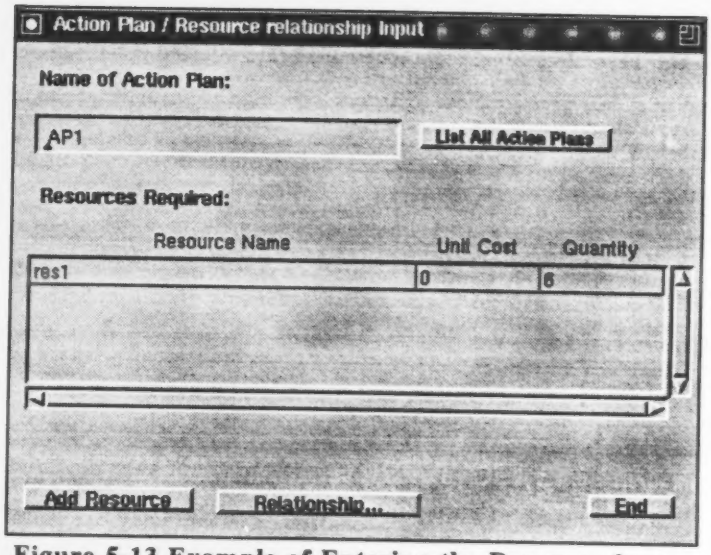

Figure 5-13 Example of Entering the Resource for an Action Plan

A *RESOURCE* object must be defined in the RCIM database before it can be specified in an *ACTION-PLAN-**is-constrained-by**-RESOURCE* relationship. Figure 5-14 is an example of the input for defining the *RESOURCE* object **res1**. The warning and critical conditions specified in the input allow the appropriate *SENSOR* and *ANALYZER* objects to be created subsequently to monitor the availability and changes in the unit cost

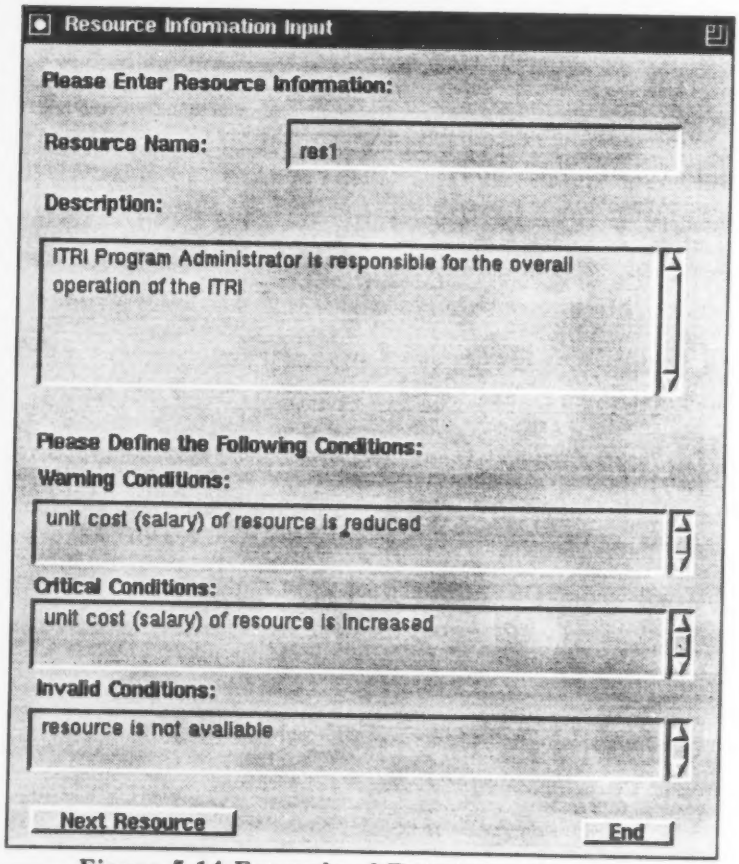

Figure 5-14 Example of Entering a Resource

of the resources.

Selecting a set of Strategic Alternatives for Implementation

Figure 5-15 illustrates the detailed processes in the *Select Strategic Alternatives* process. Once all proposals are entered into the RCIM database, the organization is ready to apply

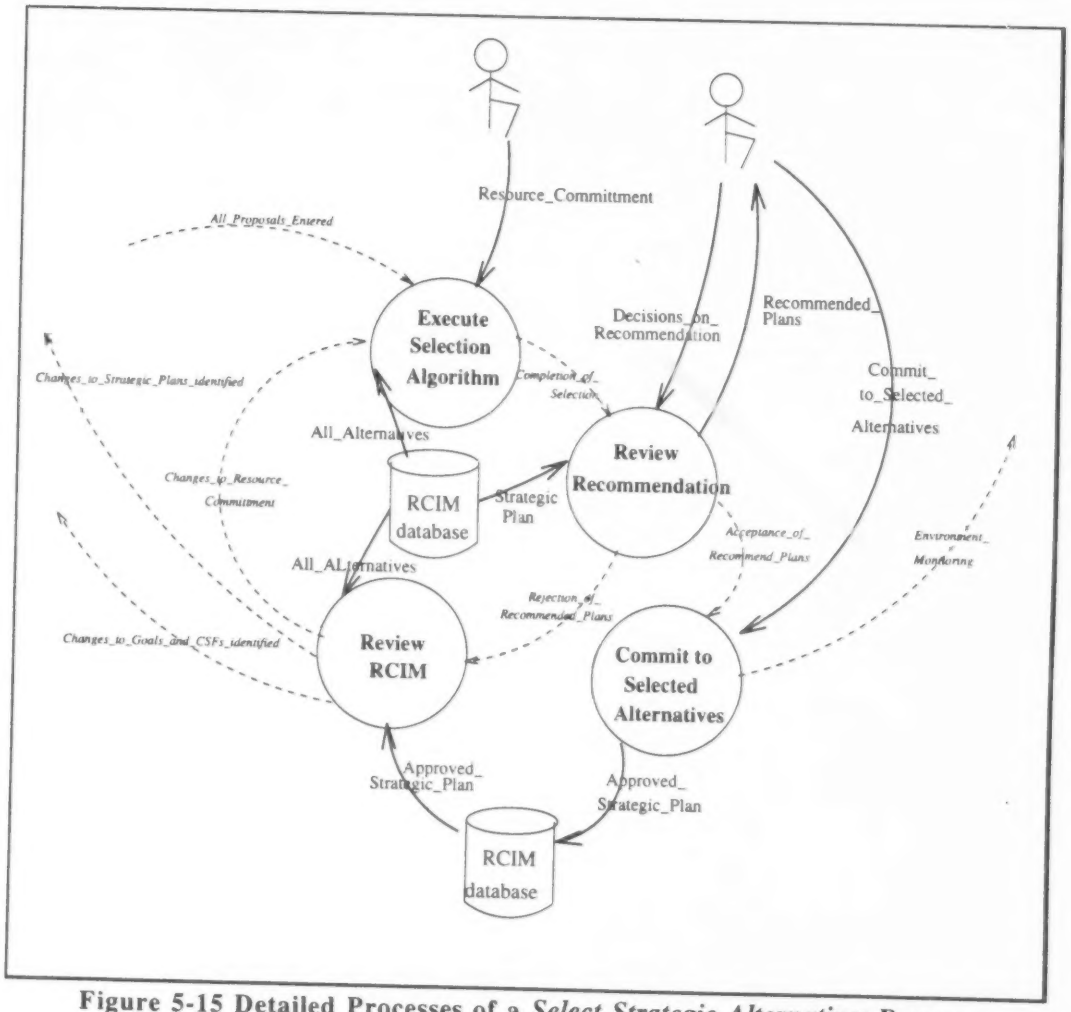

Figure 5-15 Detailed Processes of a *Select Strategic Alternatives* Process

the selection algorithm to select a set of strategic alternatives for implementation. Within the RSPPE Process, this algorithm is pre-defined to select a set of alternatives that together will accomplish as many of the high priority goals as possible within the resource limitation that the organization can commit. Before executing the selection algorithm, the user identifies the amount of resources that the organization expects to commit to the implementation of the strategic plan. A completeness checking of the responsive strategic plan in the RCIM database is also enforced by the selection algorithm. Two types of completeness checking are performed for the RSPPE process.

First, the system verifies that all *CSF* and *OBJECTIVE* objects in the RCIM database are fully supported. In the RSPPE process, each CSF must be fully supported by its set of objectives. "Full support" is indicated by a sum of 100% in the percentage contribution of the set of *OBJECTIVE* objects. Similarly, an *OBJECTIVE* object must be fully supported by a set of *OBJECTIVE* objects or a set of *ACTION PLAN* objects. Completeness checking is deferred during the construction of the responsive strategic plan to allow maximum flexibility in entering the components of the plan. However, the completeness of the plan is crucial to the execution of the selection algorithm. Hence, completeness checking is enforced prior to the execution. Execution of the selection algorithm is terminated if any of the objects are not fully supported.

Second, the system verifies that *SENSOR* and *ANALYZER* objects have been constructed for all Constraint objects defined in the RCIM database. Selection of a set of strategic

alternatives often signifies an organization's completion of the planning activities and the beginning of the action plan implementation and management control activities. Therefore, it is an optimum time to verify if focused monitoring support has been set up properly for all identified Constraint objects. If focused monitoring support has not been set up for some Constraint objects, the situation is highlighted in a warning report to senior management but the selection algorithm is still executed.

Once completeness of the responsive strategic plan has been verified, the selection algorithm is executed. The *selectionStatus* of all strategic alternatives selected by the algorithm will be set to **selected**. Figure 5-16 shows part of a report listing some of the selected strategic alternatives in the ITRI Strategic Plan. The report also indicates the goals and CSFs that will be accomplished through the implementation of the selected alternatives and the total amount of resource required. By comparing the resource commitment to the list of goals and CSFs that can be accomplished, senior management can decide if the recommended selections are acceptable or not.

If the selected strategic alternatives do not appear to accomplish an adequate number of goals, senior management can experiment with a number of what-if scenarios through various changes to the responsive strategic plan in order to find an optimum solution. As indicated in Figure 5-15, changes may include increasing the resource commitment to allow more goals to be accomplished; re-assessing the priority of the individual goal and/or CSF to ensure that the most important goals are accomplished; manually selecting

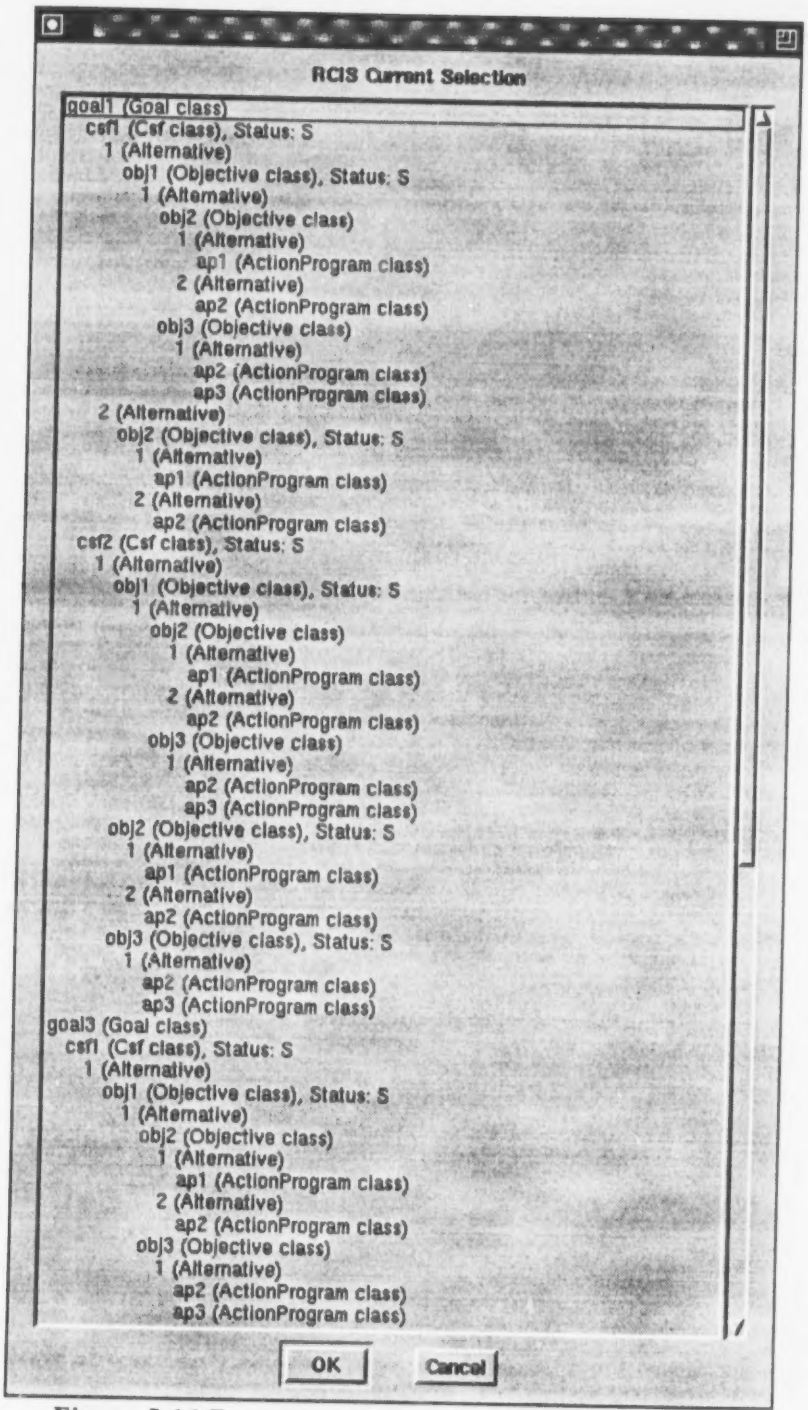

Figure 5-16 Example of Part of a Report showing all Selected Strategic Alternatives

strategic alternatives to ensure their inclusion within the set of alternatives to be implemented; or re-development of the strategic proposals to incorporate less resource-intensive strategic alternatives to accomplish the goals and objectives. Although there is no system restriction on the number and type of changes made, an organization should avoid making piece-meal changes to the responsive strategic plan. All changes should be made with the overall goals and objectives in mind. Once all changes are made, the selection algorithm can be executed again to obtain a new set of selected strategic

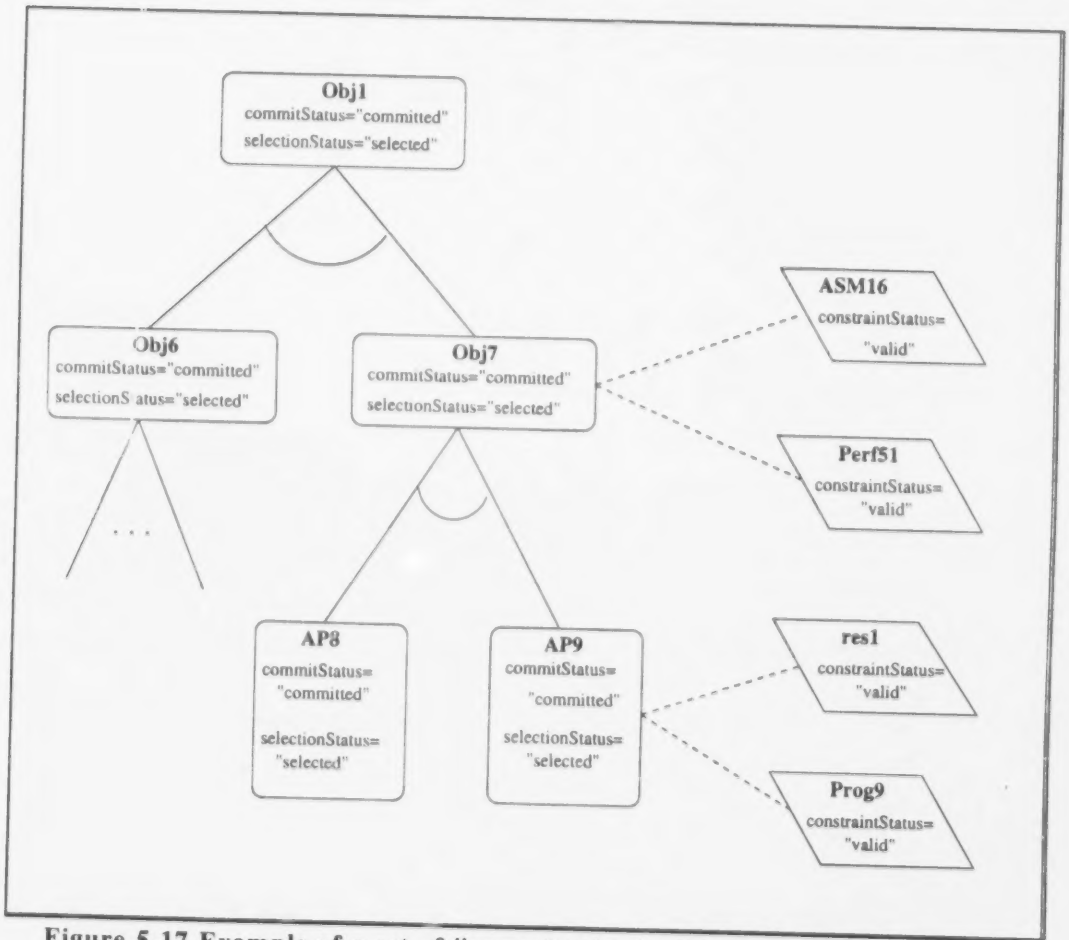

Figure 5-17 Example of a set of "committed-to" ITRI Strategic Alternatives

alternatives based on the resource commitment, and the review process is repeated.

If the recommended selections are accepted, senior management can execute the **Commit Selection** command in the SAES subsystem to set the *commitStatus* of all selected strategic alternatives to **committed**. Figure 5-17 shows the *commitStatus* of a subset of the selected strategic alternatives after the **Commit Selection** command is executed. The organization will be advised of all action plans that are committed to and implementation of the action plans can proceed.

5.5 Using the RCIS during the Management Control Phase

Within a responsive strategic management process, the transition from a strategic planning phase into a management control phase is not distinct, as is depicted in Figure 5-2. As soon as the focused monitoring support of a Constraint object is identified within the RCIM database, focused monitoring of the object can be initiated. The formal commitment to the implementation of the selected strategic alternatives marks the completion of an intensive strategic planning effort. However, the organization never ceases to plan. Table 5-2 lists the change scenarios discussed in this section. These scenarios illustrate how the RCIM supports the organization in detecting and responding to various external and internal changes in the organization environment.

Scenario	Description
1	A scenario to illustrate how the completion of an action plan is recorded in the RCIM database and its effect on the responsive strategic plan.
2	A scenario to illustrate the effect of an assumption being invalidated.
3	A scenario to illustrate how the RCIM can be used to support an organization to recognize critical changes that can impact its ability to meet its strategic goals.
4	A scenario to illustrate how new strategic initiatives can be incorporated into the RCIM during the management control phase.
5	A scenario to illustrate how the RCIM can be used to support the organization when the need to add a new goal or critical success factor arises during the management control phase.

Table 5-2 List of Change Scenarios during the Management Control Phase

Change Scenario 1: Completion of an Action Plan

In this scenario, the action plan **AP9** in Figure 5-17 is used as an example. The implementation of **AP9** is managed as a project in the organization's project management system. Focused monitoring support for the action plan **AP9** includes the *PROGRESS INDICATOR* object **Prog9** in collaboration with the *SENSOR* object **S-Prog9** and *ANALYZER* object **A-Prog9**; and the *RESOURCE* object **res1** in collaboration with the *SENSOR* object **S-res1** and *ANALYZER* object **A-res1.**

At the scheduled time, the SENSOR object **S-Prog9** accesses the Project Management database and retrieves the current status of the project implementing the action plan **AP9**. If the status of the project has changed since the last access (ie. the current status in the project management database is different from the "last-scanned" status of the project stored in the *SENSOR* object **S-Prog9**), the *ANALYZER* object **A-Prog9** analyzes the current status with respect to the conditions defined in the **Prog9**. If the current status of the project meets the requirement of the *completedCondition*, the *constraintStatus* of the *PROGRESS INDICATOR* object **Prog9** is set to **completed**.

Figure 5-18 illustrates the changes in the statuses of the various RCIM objects at the completion of the action plan **AP9**. Changing the *constraintStatus* of the *PROGRESS INDICATOR* **Prog9** to **completed** results in the *commitStatus* of the related *ACTION PLAN* object **AP9** to be set to **completed**. The status change in **AP9** triggers an evaluation in the *OBJECTIVE* object **Obj7** to assess if the *commitStatus* of all its supporting objects **AP8** and **AP9** are set to **completed**. In the example shown in Figure 5-18, **AP9** is **completed** but **AP8** is not. Therefore, the *commitStatus* of **Obj7** remains as **committed**. However, if the *commitStatus* of **AP8** is also set to **completed**, the *commitStatus* of **Obj7** will be set to **completed**, triggering an evaluation of the next higher level objective **Obj1**.

Once the action plan **AP9** is completed, its focused monitoring support is no longer needed. Therefore, a *constraintStatus* of **completed** in the *PROGRESS INDICATOR* object

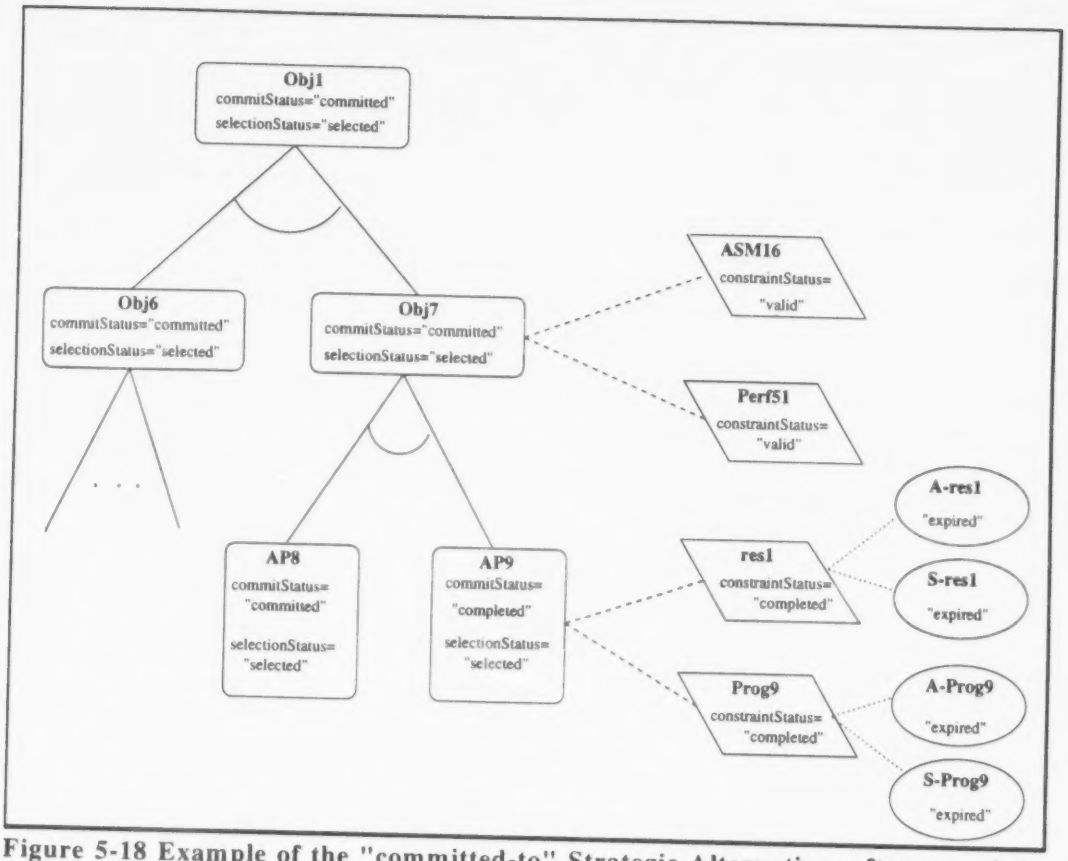

Figure 5-18 Example of the "committed-to" Strategic Alternatives after one of the Action Plan completed

Prog9 results in the removal of **Prog9** from the list of objects that will be notified about changes detected by the *SENSOR* object **S-Prog9** and *ANALYZER* object **A-Prog9** and the deletion of the associated Monitor relationship. Recalling that no RCIM object is actually deleted from the database, the objects are marked as "expired" with an expiry rationale of "**completion of action plan**". At the same time, the **completed** *commitStatus* of **AP9** also results in the *constraintStatus* of the *RESOURCE* object **res1** being set to **completed**, and the removal of the notification message of the *SENSOR* object **S-res1** and *ANALYZER* object **A-res1** to **res1.**

Change Scenario 2: Effect of an Assumption being invalidated

Once an assumption has been defined for an objective, the focused monitoring support for the assumption is activated. The direct effect of invalidating an assumption is the immediate change in state of the associated *OBJECTIVE* object to **not feasible/not committed**. Figure 5-19 is a partial view of the state model shown in Figure 3-3 to highlight this direct change. However, the indirect effect to the overall responsive strategic

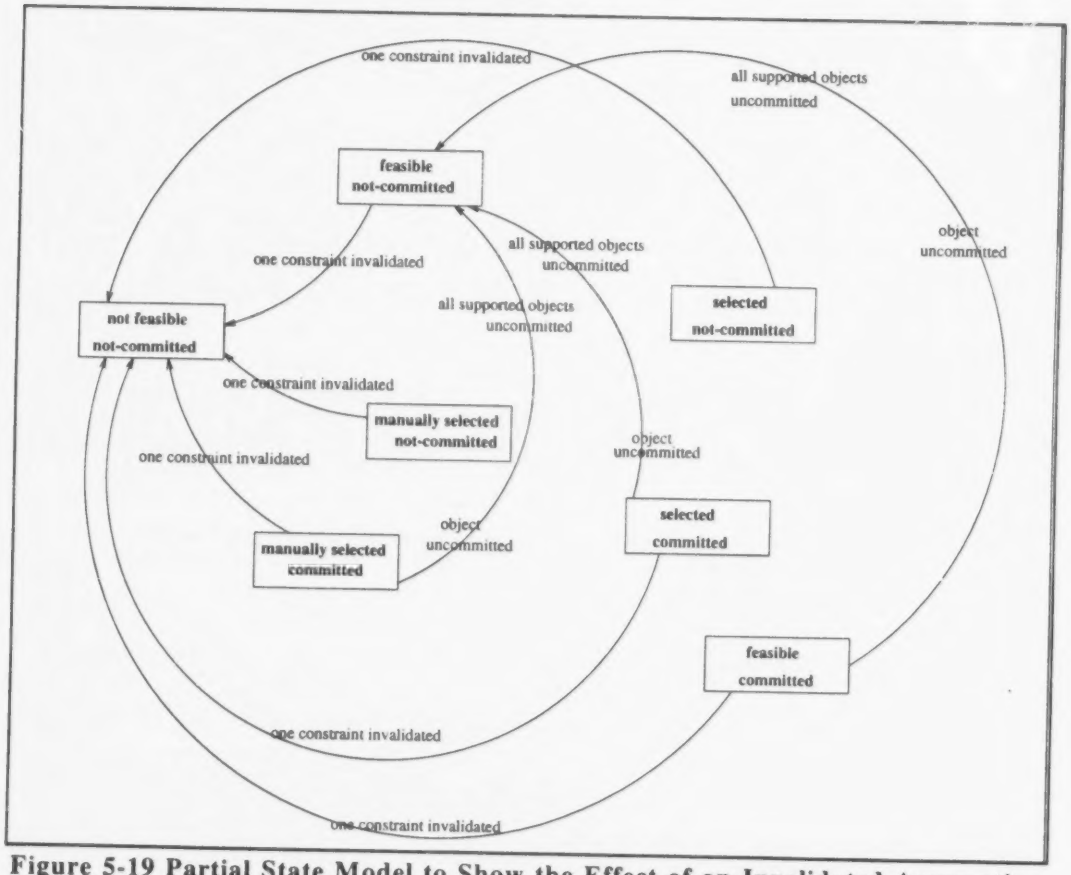

Figure 5-19 Partial State Model to Show the Effect of an Invalidated Assumption

plan depends entirely on the *commitStatus* of the *OBJECTIVE* object before the *constraintStatus* of the *ASSUMPTION* object is changed to **invalid**. If the objective is not one of the strategic alternatives that is committed for implementation, the change in status of the *ASSUMPTION* and *OBJECTIVE* objects is recorded in a *notification* report. Management can review this report on a regular basis to obtain updated information on changes in the organization environment. No corrective action may be required. However, if the objective is one that has been committed-to for implementation, the invalidation of its assumption results in a series of indirect changes in the RCIM database and a drastic response is requested from senior management.

Figure 5-20 shows the statuses of the subset of committed ITRI strategic alternatives used in Scenario 1, after the assumption **ASM16** of the **committed** objective **Obj7** is invalidated. The series of changes in the statuses can be visualized through the state changes occurring in the various related RCIM objects.

Based on the state model shown in Figure 5-19, the event "one constraint invalidated" results in the state of the objective **Obj7** being changed from **selected/committed** to **not feasible/not committed**. The state change in **Obj7** results in the event "all supported objects uncommitted" being generated for the *ACTION PLAN* objects **AP8** and **AP9**, causing the state of both **AP8** and **AP9** to change from **selected/committed** to **feasible/not committed**. Similarly, the state change in **Obj7** results in the event "one supporting object uncommitted" being generated for the *OBJECTIVE* object **Obj1**, causing

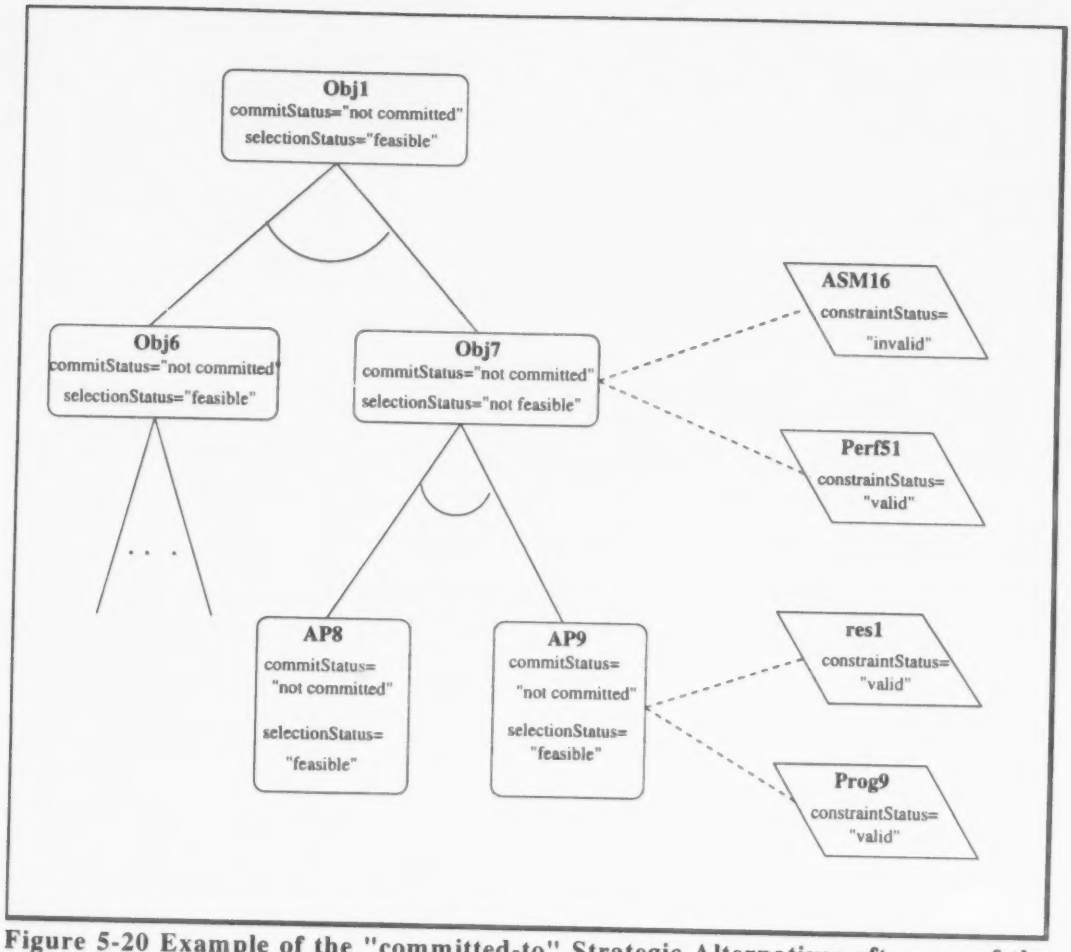

Figure 5-20 Example of the "committed-to" Strategic Alternatives after one of the Assumption is Invalidated

it to change from **selected/committed** to **feasible/not committed**. The change in state of **Obj1** in turn results in the event "all supported objects uncommitted" being generated for the supporting *OBJECTIVE* object **Obj6**, causing its status to change from **selected/committed** to **feasible/not committed** and so on until the state changes for all related StrategicPlan objects has been completed.

Management is alerted via an *imminent* report to the direct and indirect changes to the overall strategic plan. More importantly, the report identifies the impact of these changes to the accomplishment of the overall goals and CSFs. The report allows the management to decide whether or not further changes to the responsive strategic plan is required in order to maximize the available resources to achieve more strategic goals.

Change Scenario 3: Impact of critical situations developing in the organization environment

In Scenario 2, a special type of critical situation, in the form of an invalid assumption, is discussed. In the RSPPE Process, other types of critical situation are monitored using the Performance Indicator. Using the Performance Indicator **Perf1** (Figure 5-5) described in Section 5.3 as an example, the following discussion illustrates how the RCIS can assist the organization in detecting and responding to performance issues within its strategic plan.

The focused monitoring support of the Performance Indicator **Perf1** includes the *SENSOR* object **S-Perf1** (Figure 5-6), the *ANALYZER* object **A-Perf1** (Figure 5-7) and the User Interface program **UI-Perf1** (Figure 5-8). Based on the information contained in the *SENSOR* object **S-Perf1**, focused monitoring will start in Year 3. Weekly, the *ANALYZER* object **A-Perf1** executes the User Interface program **UI-Perf1** and requests the user with the userID **JSmith** to evaluate if the warning and critical conditions specified in Figure

5-5 have been reached.

If the user (ID **JSmith**) indicates that a warning condition is met, a *warning* report is generated to advise senior management that the "YTD Actual Revenue" is falling behind the "YTD Projected Revenue". Management can review the overall situations and decide if changes to the strategic plan are necessary to correct the situation. A critical condition results in a *critical* report being generated to alert management that a more drastic and prompt response is required. The RCIM support in these situations is two fold. First, it alerts management to situations developing in the environment that may impact the progress of its strategic plan. Management can then make an informed decision on whether or not corrective actions have to be taken. Second, if corrective actions are required, management is not restricted to changes in specific strategic alternatives within the strategic plan. Management can examine all related strategic alternatives available and add new alternatives if necessary. Multiple corrective action plans can be incorporated into the responsive strategic plan. The entire responsive strategic plan is then evaluated using the selection algorithm in order to obtain an updated set of selected strategic alternatives for implementation. Since the selection algorithm has been designed to select a set of alternatives to maximize the accomplishment of high priority goals with respect to the available resources, the new set of selected alternatives will maintain the focus on the achievement of the goals instead of the completion of the original selected strategic alternatives. In this way, the RCIM assists an organization to avoid the common problem of "escalating commitment" to failing or less effective action plans.

Change Scenario 4: Incorporating New Strategic Initiatives into the Responsive Strategic Plan

Modern management approaches, such as total quality management and continuous quality improvement, stress the importance of soliciting employee initiatives to help improve the overall performance of the organization. However, an evaluation process is needed to ensure that the benefits attainable through the implementation of these initiatives outweighs the cost of their implementation. When the employees realize that their initiatives will be evaluated in an open and fair manner, they will be more inclined to put their ideas forward.

The RCIM provides a framework to evaluate the benefits of the new strategic initiatives in terms of their contribution to the accomplishment of the overall strategic goals. Each initiative can be incorporated into the responsive strategic plan as one or more strategic alternatives. Figure 5-21 illustrates the addition of a new initiative as an alternative proposal to achieve the objective **Obj7**. It includes the addition of two new *OBJECTIVE* objects **Obj22 and Obj23**, and a new *ACTION PLAN* object **AP31**, and the re-alignment of the *ACTION PLAN* objects **AP8** and **AP9** under the *OBJECTIVE* objects **Obj23** from **Obj7**.

The advantage of the RCIM support is that each initiative can be incorporated into the

overall responsive strategic plan as it is received. All initiatives will be evaluated as part of the overall responsive strategic plan whenever the selection algorithm is executed. This selection may be prompted by a critical change in the environmental conditions or it may be requested specifically by senior management to ensure that the new initiatives are properly evaluated.

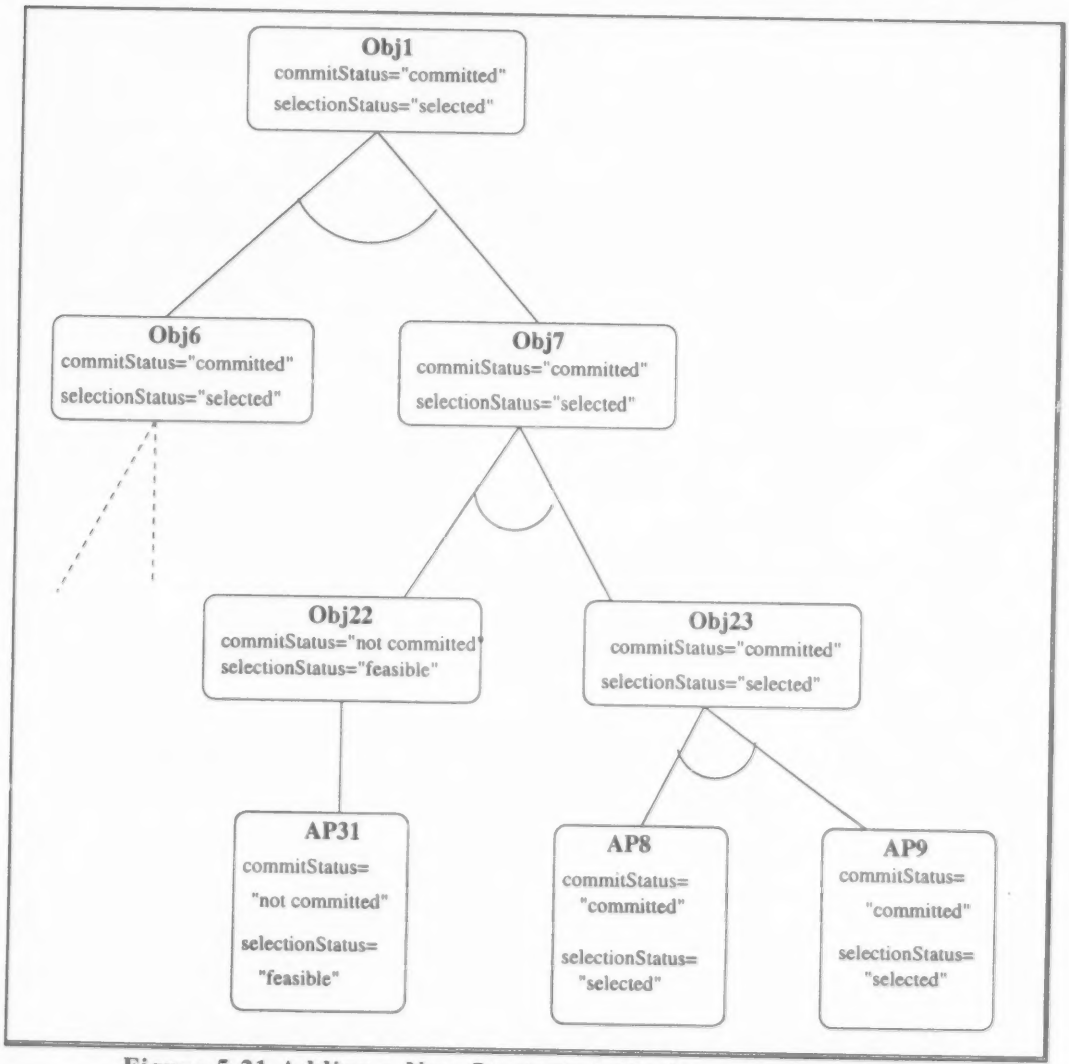

Figure 5-21 Adding a New Strategic Initiative to Support CSF1

Change Scenario 5: Discovering a new goal or critical success factors

The original ITRI strategic plan contains five goal statements and ten critical success factors. In reviewing the ITRI Strategic Plan and Business Plan, it is obvious that the viability of the Institute depends on its ability to operate as a self-supporting organization after a three-year start-up support. However, this goal is not explicitly stated in either plans. Therefore, in constructing the responsive strategic plan, **Goal6** is added to Table A-1 during the prototyping process. The goal statement of **Goal6** is stated as:

> "To operate the Information Technology Research Institute in a self-supporting mode"

At the same time, the financial support of the Institute is based primarily on the revenue generated from four areas: the Collaborative Research Program, the Technology Training Program, the Technology Consultation Program and the Corporate Membership Program. While the first three programs were included as critical success factors in the ITRI Strategic and Business Plans (specifically **CSF1**, **CSF4**, and **CSF5**), Corporate Membership which is expected to generated the majority of the financial support for the ITRI administrative funding was not included. **CSF11** is therefore added to the list of CSF in Table A-2. Similarly, the successful performance of the ITRI Administration is also critical to the accomplishment of **Goal6** and is added as **CSF12** in Table A-2. Figure 5-22 illustrates the relationship between the ITRI goals and CSFs shown in Table A-1 and A-2.

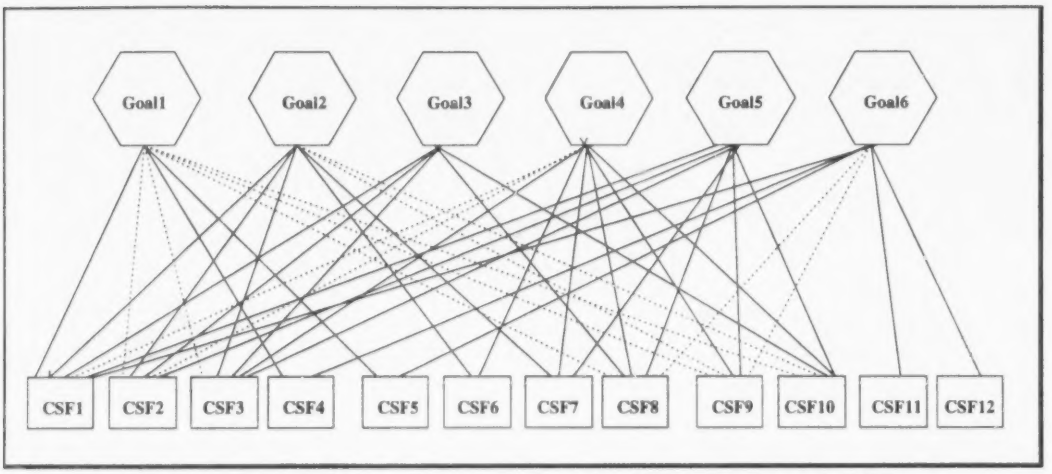

Figure 5-22 Relationships between the ITRI Goals and CSFs

Although the new goal and CSFs are discovered during the prototype process and may not represent a normal part of any strategic management process, it does point out the difficulty of a "complete" planning process. Strategic planning is an evolutionary process. At any point in the process, the organization may need to modify the original plan and re-plan.

The difficulty in the replanning comes in the integration of the new discovery with all the existing plans. In the example in this scenario, no new action plan or objectives need to be added to the overall plan since the missing goal and critical success factors were considered in the original plan even though they were not explicitly stated. The integration effort therefore involves identifying the relationships between the existing goals and CSFs with the newly discovered ones. The importance of **Goal6** translates into a high priority rating of 5. This changes the order of selection of all the strategic alternatives and can substantially change the set of committed alternatives. However, the

new selection will effectively integrate the new goal and CSF into the overall plan and result in a set of committed action plans that maximize the overall goals. Such integration is difficult to achieve without the support of a RCIM.

In most cases, addition of new goals and CSFs is accompanied by new strategic alternatives to accomplish the goals. Without the RCIM support, such addition will have to be treated as a separate strategic management process. Fragmentation of the strategic management process can lead to ineffective use of the organization resources. The RCIM therefore provides a framework for integrating the organization's strategic management processes.

Chapter 6

Conclusions and Future Works

Effective strategic management is crucial to the long term success of an organization. To increase the return on investment of an organization's information systems resources, the opportunity to utilize these resources in the direct support of the organization's strategic management process cannot be overlooked. A responsive strategic management process is developed in this research. The process is designed to address the issues of strategic management within a dynamic organization environment. It is enabled by IT support, a key component of which is a responsive corporate information model that utilizes the organization's information systems in the support of its strategic management process. This concluding chapter of the dissertation outlines the contributions of this research and future directions for related research.

6.1 Contributions

The contributions of this research cover two disciplines: organization management and

information technology. For the management discipline, the following contributions are identified:

1. Development of a responsive strategic management process to address the challenge of a dynamic organization environment

The responsive strategic management process developed in this research is a prescriptive, rational process designed to address the issues of strategic management in a dynamic environment. Effective strategic management is critical to the long term success of an organization. The challenge of a dynamic environment demands a management approach that deals with the frequency and urgency of the changes in the organization environment.

The uniqueness of the responsive strategic management process lies in its emphasis on continuous planning throughout the management control phase. It focuses the organization's attention on the accomplishment of the organization goals instead of the successful implementation of the selected action plans. It utilizes the goals, objectives, and action plans developed during the goal-setting phase and strategic planning phase to build a responsive strategic plan. This plan is then used to support the organization in responding to changes in the environment throughout the management control phase. The plan enables the organization to promptly identify environmental changes that may impact the organization's ability to achieve the strategic goals and objectives; promptly identify the direct and indirect impact of the changes; and promptly identify the alternative action plans.

The key to the responsive strategic plan is in the simultaneous exploration and maintenance of all strategic proposals. Each proposal has been developed based on different assumptions about the environmental conditions and different performance expectations. The collection of alternative proposals provides the organization with 'pre-defined' corrective actions to respond to changing environmental conditions. In addition, the responsive strategic plan facilitates the set up of a perception plan using the identified assumptions and performance indicators. This perception plan is then used to support focused environmental monitoring.

The conceptual basis of the responsive strategic management process is adapted from the reactive reasoning and planning concepts used in the control of autonomous robots operating in dynamic and hazardous environments. The process is enabled by IT support, a key component of which is the responsive corporate information model (RCIM) described in Section 3.1. The strategic proposals are implemented in the RCIM using the various StrategicPlan Object Types, while the focused monitoring support is implemented through the collaboration of the Constraint, Sensor and Analyzer Object Types. Several scenarios are described in Section 5.5 to illustrate how the RCIM facilitates the responsive management of the organization's strategic proposals with respect to the changes in the environment.

2. Development of a framework to complement current BPR tools

BPR advocates drastic changes to business processes in order to gain competitive

advantages. However, existing methodology and tools provide little or no support to manage the changes that result directly or indirectly from the implementation of the new processes By actively supporting environmental monitoring and the management of the changes, the responsive strategic management approach provides much needed support to the implementation phase of the BPR projects. Details of how the responsive approach can be applied within the BPR context are discussed in Section 2.6.

3. Development of a framework to facilitate the organization's continuous improvement process.

The RCIM is unique in its capability to incorporate new strategic initiatives into the responsive strategic plan. New initiatives can be incorporated at any point during the strategic management process and the model ensures that all initiatives are evaluated with respect to their contribution to the overall goals and their resource requirements (refer to Change Scenario 4 in Section 5.5 for details). When employees realize that their initiatives will be evaluated in an open and fair manner, they will be more inclined to put their ideas forward. The framework therefore facilitates continuous improvement within the strategic management process.

4. Development of a framework to facilitate organization learning by capturing the historical data to study an organization's strategic decisions and decision making process.

An important contribution of the RCIM is its support for organization learning through

the implementation of decision logging. The importance of organization learning is discussed in Section 2.4. Section 3.1 contains discussions of how logging is designed within the RCIM to collect data about the strategic alternatives that are selected/committed, plus the assumptions and constraints in effect at the time. The data allows the organization to re-create its overall strategic plan as of a particular point in time in order to study the basis of its decisions. Valuable information about the organization's decision making process can also be obtained through analysis of the overall strategic plan.

For the information technology discipline, the following contributions are identified:

1. Extension of simple organization modelling into the domain of strategic management

The major contribution of this research is the extension of prior research in organization model into the domain of strategic management. The RCIM is an extension of Chen's work on the IOIS model [Chen 88] into a more in-depth model to support the dynamics of unstructured decisions.

Explicit modelling of unstructured decisions was identified by Gorry and Scott Morton as an effective way of improving an organization's knowledge and experience with their decision making [Gorry & Scott Morton 89]. Improved understanding gradually transforms an unstructured decision into a structured decision, providing the opportunity

for automation of the decision making process. This thesis research was motivated by the belief that the key in addressing the ACM challenge of "modelling reality and managing complexity" [Frailey 91] lies in understanding the complexities of the real world and in being able to express them in appropriate information models so tools and methods can be configure to analyze and manage the complexity.

The RCIM enables the organization to explicitly model the characteristics and relationships of the strategic plan components using the various Object Types and Relationship Types, and to model the complex interactions between the components through the object state changes (refer to Session 3.1 for details). While this model allows the organization to capture the relevant information with respect to its strategic decisions, it also captures and expresses the knowledge of the complex strategic management process in the design of the RCIM. This knowledge can be built upon through critical review and field tests of the RCIM, and the model can be enhanced to capture the increased knowledge. The model therefore supports the development of knowledge about the strategic management process. At the same time, the meta-system approach used in the design of the RCIM allows an organization to customize the model to support the organization's culture and strategic management practice.

The modelling process also provides an opportunity to explore and configure tools and methods to help in the management of the strategic plan. For example, a graphical overview of the responsive strategic plan was found to be highly desirable during the

prototyping exercise of the ITRI Strategic Plan. Text-based reports, such as the Selected Strategic Alternatives Report shown in Figure 5-16, are less intuitive than graphical presentations such as the graphical view of the strategic proposal shown in Figure 5-9. A graphical browser is therefore identified as a desirable tool. Building on the design of the RCIM, a graphical browser is configured to display the information captured in the RCIM database. A copy of the requirements definition of the graphical browser is included in Appendix C. Other tools identified during the prototyping process include the tool described in Section 5.3 to support the Analytic Hierarchy Process to capture the subjective data typical in unstructured decisions, and the tool described in Section 5.4 to guide the strategic planners through the responsive planning process. Field test of the RCIM will undoubtedly identify other tools. The RCIM therefore provides the base upon which tools and methods can be configured to assist in the management of the complex strategic management process.

2. Extension of the organization model with the active agent concept

Another major contribution of this research is the incorporation of the active agent concept within the RCIM to support the continuous monitoring of crucial environmental conditions and alert management to the changes appropriately. Chen's work on Context-based Information System [Chen 92, Chen 95a] describes how the IOIS model can make use of an organization's information systems to provide contextual information within an executive information system. By incorporating active agents in the design of the Object Types (refer to Section 3.1 for details), the RCIM integrates the information systems into

the support of the strategic managment process on a continuous basis. This integration positions existing information systems in the direct support of key management activities, allowing an organization to increase the return on its IT investment.

3. Providing a framework to meet the demands of the rapidly changing executive information requirements.

The difficulty in supporting executive information requirements lies in the rapid changes in the requirements. The broad-scoped nature of the executive decisions requires a flexible information structure to co-ordinate both the automated information support (through the organization's information systems) and the manual support (through the organization's environment monitoring group). As discussed under the subheading of "Entering a CSF and its Performance Indicators" in Section 5.3, the design of the Analyzer Object Types provides an organization with the flexibility to switch from an interim manual support to environmental monitoring to an automated support as soon as the required application programs are developed. This design feature enables the organization to meet the demands of the rapidly changing executive information requirements while ensuring that the need for new application program development is captured and attended to over time.

4. Adaptation of the reactive reasoning and planning concepts used in the control of autonomous robots to assist in strategic management.

An important contribution of the RCIM is the extension of the reactive reasoning and planning concepts used in the control of autonomous robots to applications in less

structured decision domains

The adaptation of the reactive concepts is prompted by the similarities between the dynamic environments in which the robot and the organization operate (refer to Section 2.2 for details). However, the strategic decisions facing the organization are often less structured than those faced by the robots. Adaptation of the reactive concepts are necessary to handle the differences. For example, the discussion in Section 2.4 outlines how interactive decision support is incorporated in the design of the RCIM instead of traditional AI planning approaches in the design of the Theo-Agent [Mitchell 90] to deal with unanticipated situations.

This research identifies two areas where IT can support strategic management in a dynamic environment, namely, the management of alternative solutions to allow prompt identification of viable alternatives as the environment changes; and the focused monitoring support to assist in the prompt identification of the changes. Issues relating to planning in a dynamic environment are common in other areas such as software development. The application of similar IT support to other dynamic planning environments is worth exploring.

At the same time, this research highlights the growing importance of a multi-disciplinary approach to information technology research. IT has matured enough to address real-life business and management issues in ways that were not possible before. Solutions for some

of these issues may be readily available from areas of research that are not business or management related. Collaboration across disciplines can accelerate the return on investment in IT research and development.

5. Providing a general model to support both time-scheduling and performance-related types of constraints.

Planning tools such as project management systems have long been used to address time-scheduling constraints. However, planning involves more than time-scheduling constraints. The design of the Constraint Object Type, with the provision of the five constraint conditions, is an important contribution in that it can be customized to support both time-scheduling and performance-related types of constraints. The process involved in defining customized Constraint Object Types for an organization is discussed in Section 3.3.

6.2 Future Research

This research explores the issues of strategic management in a dynamic environment and proposes a responsive strategic management process designed to address the issues. The process depends on the RCIM to manage the strategic proposals through the changes in the environment. A prototype system has been built to demonstrate the feasibility and benefits of the process and the RCIM. The following have been identified as future research directions:

1. Field Test of the RCIM.

The feasibility and potential benefits of the responsive strategic management process and the RCIM are illustrated using the prototype system and the ITRI as an example organization. The limitation of using a non-operational organization such as the ITRI was acknowledged in Section 1.3. Validation of the proposed process and the RCIM through a field test with an operational organizations is an important next step of this research.

The main objective of the field test is to study the usefulness of the RCIM in improving managerial effectiveness. The responsive strategic management process and the RCIM are designed to improve the responsiveness of the organization with respect to prompt detection of the changes, prompt identification of the impact and prompt identification of the alternative actions. The field test should therefore include pre-tests and post-tests to assess the effectiveness and responsiveness of the organization strategic management process and decisions before and after the use of the RCIM. Structured questionnaire interviews, commonly used in empirical studies in management science research, may be used as assessment tools.

The field test should be at least one year in duration since a major review and update of the strategic management goals and objectives is typically done on an annual basis, to coincide with the budgetary cycle. The one-year duration will allow the observation and data collection of at least one complete revision cycle of the strategic plan.

Data collected from the pre-tests and post-tests must be analyzed to provide a comparison between the responsiveness of the organization before and after the use of the RCIM. It is necessary to note that the data represents the experience of one organization's use of the RCIM and may be biased by the organization's learning capability and/or the type of changes occurring during the empirical study. Ideally, several field tests are required to build up a case-based inventory of RCIM experience in order to isolate some of the organization dependent factors.

To be a candidate for the field test, an organization must meet the following criteria:

- has some experience and expertise in strategic management,
- able to start a new strategic management cycle, ie. at a stage ready to develop new vision, goals and objectives,
- has a basic level of IT investment, ie. the organization must have some application systems that can be used to support the strategic management process,
- has an open management philosophy, ie. senior management committed to information sharing and data-based decision making, and receptive to staff initiatives.

In addition, senior management support is crucial to the success of the field test.

2. An integrated tool environment to support the use of the RCIM as an effective executive decision support system.

Several tools were identified during the prototyping process of the RCIM, eg. the tool

described in Section 5.3 to support the Analytic Hierarchy Process to capture the subjective data; the tool described in Section 5.4 to guide the strategic planners through the responsive planning process; and the graphical browser described in Section 6.1 for the responsive strategic plan. Field test of the RCIM will undoubtedly identify other tools. Tools are crucial to allow the RCIM to be used effectively by the executives. Research to develop an integrated tool environment to incorporate these tools into the RCIM is crucial. In fact, the development of a graphical browser for the RCIM has proceeded and a copy of the requirements definition document is included in Appendix C.

3. Development of a RCIM Meta System.

The issue of tool integration highlights the need to develop an RCIM meta system. The importance of being able to customize a RCIM to an organization's culture and practice was discussed in Sections 2.5 and 2.7. The design of the generalized RCIM model provides some insights to the common attributes of the RCIM objects. However, the design needs to be generalized further to form a meta-system to support the customization of the RCIM. In addition, the RCIM objects are implemented in the prototype system as Smalltalk objects and are not persistent. Therefore, the design of the meta-system should include a persistent object database management system for the RCIM objects.

4. Extension of the RCIM modelling capability

The existing RCIM is customized for Firdman's Strategic Planning/Plan Execution Process [Firdman 91] which is a relatively basic but practical strategic management process. This

basic model can be enriched by incorporating research in other IT areas to extend it into a more advanced model. Example of such technologies include inferencing with uncertainty, and version management in support of planning scenarios.

Recent research in Artificial Intelligence have explored the impact of uncertainty on decision making [Kanal & Lemmer 86, Parsaye & Chignell 88]. Various representations and methods are available for modelling and inferencing uncertainty in decisions. The major ones include Bayesian probabilities, Dempster-Shafer Theory of Evidence, Certainty Theory and fuzzy sets [Turban 93]. Turban points out that in the real world, uncertainty is a serious problem in decision making that have not been adequately addressed by most decision making model. Investigation into how the RCIM can be extended to handle uncertainty therefore presents an interesting research opportunity. Initial thoughts on extension have centered around the addition of an *uncertaintyFactor* attribute in the Constraint Relationship Types. More work is required to investgate how the different representations and methods can be handled.

Extension to incorporate version management in the RCIM to support multiple planning scenarios is also worth exploring. The ability to develop and maintain multiple scenarios allows for more in-depth study of the potential impact of changes. This ability enhances the effectiveness of the RCIM as a forecasting and planning tool. The extension to the RCIM provides an interesting version management research application in the object database management system area.

5. Analysis of the strategic decisions and the decision making process.

The benefits of the RCIM include the support for a strategic management process and the capture of the organization's experience with respect to its strategic decisions and decision making process. The decision logs within the RCIM are designed to collect the data; however, additional research is required to explore how this data can be effectively used. Examples include understanding the relationship between the breadth of the decision tree (the number of alternatives) and the organization's knowledge and experience about the decision; the relationship between the number of occurrences of critical and warning statuses in the resource constraints and the quality of the strategic proposals and resource estimates; the relationship between the organization's communication pattern (openness) and the use of the **manual selection** feature of the RCIM. The information gained from the analysis of the data can be used by an organization to improve its decisions and decision making process.

6. Extension of the data security and data protection features of the RCIM.

Effective strategic management is critical to the success of an organization and therefore, protection of the strategic planning information is important. While the RCIM facilitates the sharing of strategic management information to improve the planning process within the organization, the need for data security and protection is also recognized. At present, rudimentary security protection is supported using user identification and password protection. However, more detail analysis of the issues and an investigation of possible solutions are necessary.

Bibliography

[Agnew & Brown 86]
Agnew, N.M., and Brown, J.L., "Bounded Rationality: Fallible Decisions in Unbounded Decision Space", Behavioral Science, Volume 31, 1986.

[Agre & Chapman 97]
Agre, P., and Chapman, D., "Pengi: An Implementation of a Theory of Activity", Proceeding of AAAI'87, pp. 268-272, 1987.

[Aguilar 67]
Aguilar, F., Scanning the Business Environment, New York: MacMillan, 1967.

[Anderson et al 92]
Anderson, D.R., Sweeney, D.J., and Williams, T.A., Quantitative Methods for Business, 5th edition, West Publishing Company, St Paul, MN, 1992.

[Angehrn & Jelassi 94]
Angehrn, A.A., and Jelassi, T., "DSS Research amd Practice in Perspective", Decision Support Systems 12, Elsevier Science B.V., North-Holland, pp. 267-275, 1994.

[Applegate & Osborn 89]
Applegate, L.M. and Osborn, C.S., "Philip 66 Comapny: Executive Information Systems", Harvard Business School Publication 9-189-006, 1989.

[Argyris 82]
Argyris, C., "Organizational Learning and Management Information Systems, Data Base, Vol 13, No. 2 & 3, pp. 3-11, Winter 1982.

[Argyris & Schon 78]
Argyris, C., and Schon, D.A., Organizational Learning: A Theory of Action Perspective, Reading, M.A., Addison-Wesley, 1978.

[Arinze 91]
Arinze, B., "A Contingency Model of DSS Development Methodology", Journal of Management Information Systems. Vol. 8, No. 1. pp.149-166., Summer 1991.

[Arinze 92]
Arinze, Bay, "A User Enquiry Model for DSS requirements analysis: a framework and case study", International Journal of Man-Machine Studies, Vol. 37, No. 2, pp.241-264, August 1992.

[Barney & Griffin 92]
Barney, J.B. and Griffin, R.W., The Management of Organizations: Strategy, Structure, Behaviour, Houghton Mifflin Company, Boston, MA, USA, 1992.

[Barrett 94]
Barrett, J.L., "Process Visualization: Getting the Vision Right is Key", Information Systems Management, pp. 14-23, Spring 1994.

[Basili 92]
Basili, V.R., "Software Modelling and Measurement: The Goal/Question/Metric Paradigm", University of Maryland, Technical Report CS-TR-2956 (UMIACS-TR-92-96), September 1992.

[Basili & Rombach 88]
Basili, V.R. and Rombach, H.D., "The TAME Project: Towards Improvement-Oriented Software Environments", IEEE Transaction on Software Engineering, Vol. SE-14, No. 6, June 1988.

[Basili & Weiss 84]
Basili, V.R. and Weiss, D.M., "A Methodology for Collecting Valid Software Engineering Data", IEEE Transaction on Software Engineering, Vol. SE-10, No. 6, November 1984.

[Blanning 87]
Blanning, R.W., "An Object-Oriented Paradigm for Organization Behavior", Transactions on DSS-87, pp. 87-94.

[Bourgeois & Eisenhardt 88]
Bourgeois, L.J. III, and Eisenhardt, K.M., "Strategic Decision Process in High Velocity Environments: Four Cases in the Microcomputer Industry", Management Science, Vol. 34, No. 7, pp. 816-835, 1988.

[Bowen 87]
Bowen, M.G., "The Escalation Phenomena Reconsidered: Decision Dilemmas or Decision Errors?", Academy of management Review, pp. 52-66, January 1987.

[Boyton & Zmud 87]
Boyton A.C., and Zmud, R.W., "Information Technology Planning in the 1990's: Directions for Practice and Research", MIS Quarterly, pp. 59-71, March 1987.

[Bradley et al 95]
Bradley, P., Browne, J., Jackson, S., and Jagdev, H.S., "Business Process Re-engineering (BPR) - A Study of the Software Tools Currently Available", Computers in Industry, Vol. 25, Iss. 3, pp. 309-330, March 1995.

[Brookes 86]
Brookes, C.H.P., "Requirement Elicitation for Knowledge Based Decision Support Systems", Decision Support Systems: A Decade in Perspective. Proceedings of the IFIP WG 8.3 Working Conference. pp.129-144.North-Holland, Amsterdam, Netherlands, June 1986.

[Brookes 88]
Brookes, C.H.P., "An automated DSS Requirement Elicitation Model applied to Non-repeating Problem Situations", Organizational Decision Support Systems. Proceedings of the IFIP WG 8.3 Working Conference. PP.129-138. North-Holland, Amsterdam, Netherlands, 1988.

[Brooks 91]
Brooks, R.A., "Intelligence without Reason", Proceedings IJCAI-91, pp. 569-595, 1991.

[Brooks 86]
Brooks, R.A, "A Robust Layered Control System for a Mobile Robot", IEEE Journal of Robotics and Automation 2(1), March 1986.

[Bukszar & Connelly 88]
Bukszar, E. and Connelly, T, "Hindsight Bias and Strategic Choice:Some problems Learning from Experience", Academy of Management Journal, pp. 628-641, September 1988.

[Byrd 92]
Byrd, T.A., "Implementation and Use of Expert Systems in Organization: Perceptions of Knowledge Engineers", Journal of Management Information Systems, Vol.8, No.4, pp.97-116, Spring 1992.

[Carley 92]
Carley, K., "Organizational Learning and Personnel Turnover", Organization Science, Vol. 3, No. 1, pp.20-46, 1992.

[Cartin 93]
Cartin, T.J., Principles and Practices of TQM, ASQC Quality Press; White Plains, N.Y.: Distributed by Quality Resources, 1993.

[Cassidy 90]
Cassidy, J., "Strategic Issues Management: An Integrated Systems View", Strategic

Management: Methods and Studies, edited by Dean, B.V., and Cassidy, J.C., Elsevier Science Publishing Company Inc., New York, NY 10010, USA, 1990.

[Chen 76]
Chen, P.P., "The Entity-Relationship Model: Toward a Unified View of Data", ACM Transactions on Database Systems, Vol. 1, No. 1, pp. 33-37, March 1976.

[Chen 88]
Chen, M., The Integration of Organization and Information System Modelling: A Metasystem Approach to the Generation of Group Decision Support SYstems and Computer-aided Software Engineering, PhD Thesis, University of Arizona, 1988.

[Chen 92]
Chen, M., "Contextual Information Systems: A Metasystem Environment for Systems Development and Delivery", Presentation Notes: 1st International Summer School on Metamodelling and Methodology Engineering, University of Jyvaskyla, Finland, June 1992.

[Chen 95a]
Chen, M., "A Model-Driven Approach to Accessing Managerial Information: A Repository-Based Executive Information System", Journal of Management Information Systems, Vol. 11, No. 4, pp. 33-63, Spring 1995.

[Chen 95b]
Chen, M., A Comparison of BPR Methodologies, Presentation Notes, National BPR'95 Conference, Arlington, VA, September 1995.

[Chen & Nunamaker 89]
Chen, M. and Nunamaker, J.F. Jr., "Integration of Organization and Information Systems Modeling: An Object-Oriented Approach", Proceedings of the 22nd Hawaii International Conference of Systems Science, pp 70-79, January 1989.

[Chen et al 89]
Chen, M., Nunamaker, J.F. Jr., and Weber, E.S., The Use of Integrated Organization and Information Systems Models in Building and Delivering Business Applications Systems, IEEE Transactions on Knowledge and Data Engineering, Vol. 1, No. 3, September 1989.

[Chen et al 91]
Chen, M., Liou, Y.I., and Weber, E.S., "Developing Intelligent Organizations: A Context-Based Approach to Individual and Organizational Effectiveness", Special Issue of Journal of Organizational Computing on Cognitive Science and Artificial Intelligence in Organizational Modelling, September 1991.

[Churchman et al 57]
Churchman, C.W., Ackoff, R.L., and Arnoff, E.L., Introduction to Operation Research, John S. Wiley, New York, 1957.

[Ciborra 88]
Ciborra, C.U., "Knowledge and Systems in Organization: a Typology and a Proposal" , Organization Decision Support Systems, edited by R.M.Lee, A.M. McCosh and P. Migiliarese, Elsevier Science Publishers B.V., North-Holland, IFIP, 1988.

[Clemons & Weber 90]
Clemons, Eric K. and Weber, Bruce W., "Strategic Information Technology Investments: Guidelines for Decision Making", Journal of Management Information Systems, Fall, 1990, Vol. 7, No.2, pp.9-28, 1990.

[Coad & Yourdon 90]
Coad, Peter, and Yourdon, Edward, Object-oriented Analysis, Prentice Hall, 1990.

[Cole 91]
Cole, R.E., "Target Information for Competitive Advantage", The Information Infrastructure, Harvard Business Review Book Series, 1991.

[Collins & Gentner87]
Collins, A., and Gentner, D., "How people constuct mental models, Cultural Models in Lnaguage and Thought, B. Holland and N. Quinn (editors), Cambridge: Cambridge University Press, 1987.

[Copalakrishnan 88]
Copalakrishnan K.N., The Design of a Capacity Requirements Planning Systems and a Decision Support System for Strategic Planning, MSc Thesis, 1988.

[Daft 92]
Daft, R., Organization Theory and Design, West Publishing Company, St. Paul, MN, 1992.

[Davenport & Short 90]
Davenport, T.H., and Short, J.E., "The New Industrial Engineering: Information Technology and Business Process Re-design", Sloan Management Review, pp. 11-27, Summer 1990.

[Davis & Olson 85]
Davis, G.B., and Olson, M.H., Management Information Systems: Conceptual Foundations, Structure and Development, New York, McGraw Hill, Second Edition, 1985.

[de Compos & Monteiro de Macedo 92]
de Compos, A. M., and Monteiro de Macedo, M.J., "A Blackboard Architecture for Perception Planning in Autonomous Vehicles, Proceedings of the 1992 International Conference on Industrial Electronics, Control, Instrumentation, and Automation. Power Electronics and Motion Control, Vol. 2, pp. 826-831, 1992.

[Dean & Cassidy 90]
Dean, B.V., and Cassidy, J.C., Strategic Management: Methods and Studies, Elsevier Science Publishing Company Inc., New York, NY 10010, USA, 1990.

[DEC 92]
Digital Equipment Corporation, DECmodel - Modeler's Guide, Rev X1.2, Marlborough, MA, 1992.

[DeMarco 78]
DeMarco, T., Structured Analysis and Systems Specification, New York, Yourdon Inc., 1978.

[Dennis et al 94]
Dennis, A.R., Daniels, R.M. Jr., Hayes, G., and Nunamaker, J.F. Jr., "Methodology-driven Use of Automated Support in Business Process Re-engineering, Journal of Management Information Systems, Vol. 10, Iss. 3, pp. 117-138, 1994.

[Dondi et al 88]
Dondi, C., Migliarese, P., Moia, G. and Salamone, G., "An Organization Decision Support System for Italtel Projects and Internal Resource Planning", Organization Decision Support Systems, edited by R.M.Lee, A.M. McCosh and P. Migiliarese, Elsevier Science Publishers B.V., North-Holland, IFIP, pp 43-58, 1988.

[El Sawy 85]
El Sawy, O.A., "Personal Information Systems for Strategic Scanning in Turbulent Environments: Can the CEO Go On-Line?", MIS Quarterly, Vol 9, No. 1, pp. 53-60, 1985.

[Elam et al 86]
Elam, J.J., Huber, G.P. abd Hurt, M.E., "An Examination of the DSS Literature (1975-1985)", Decision Support Systems: A Decade in Perspective, E.R.McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North-Holland), IFIP, pp.1-17, 1986.

[Elofson & Knosynski 91]
Elofson, G., and Konsynski, B., "Delegation technologies: Environmental Scanning with Intelligent Agents", Journal of Management Information Systems, Vol. 8, No. 1, pp. 37-62, Summer 1991.

[Fedorowicz & Konsynski 92]
Fedorowicz, J. and Konsynski, B., "Organization Support Systems: Bridging Business and Decision Processes", Journal of Management Information Systems. Vol. 8, No. 4, pp.5-25, Spring 1992.

[Firby 89]
Firby, R. J., Adaptive Execution in Complex Dynamic Worlds, PhD Thesis, Yale University, 1989.

[Firby 87]
Firby, R.J., "An Investigation into Reactive Planning in Complex Domains", Proceedings of AAAI'87, pp. 202-206, 1987.

[Firdman 91]
Firdman, H.E., Strategic Information Systems: Forging the Business and Technology Alliance, McGraw-Hill, US, 1991.

[Fortune 84]
"Knowing Your Competitors", Fortune, May 14, 1984.

[Frailry 91]
Frailry, Dennis J., Managing Complexity and Modelling Reality: Strategic Issues and an Action Agenda from the 1990 ACM Conference on Critical Issues, ACM Press, 1991.

[Fredericks & Venkatraman 88]
Fredericks, P. and Venkatraman, N., "The Rise of Strategy Support Systems", Sloan Management Review, Spring 1988, pp.47-54, 1988.

[Frederickson & Mitchell 84]
Frederickson, J.W., and Mitchell, T.R., "Strategic management Processes: Comprehensiveness and Performance in an Industry with an Unstable Environment", Academy of Management Journal, pp.399-423, 1984.

[Frederickson 84]
Frederickson, J.W., "The Comprehensiveness of Strategic Decision Making Processes: Extentions, Observations, Future Directions", Academy of Management Journal, pp. 445-466, 1984.

[Gat 92]
Gat, E., "Integrating Planning and Reacting in a Heterogeneous Asynchronous Architecture for Controlling Real-world Mobile Robots", Proceedings of the AAAI'92, pp. 809-815, 1992.

[Gendelev 92]
Gendelev, B., "MIS and Marketing: Secrets of Strategic Information Mining", Chief Information Officer Journal, pp. 12-23, Summer 1992.

[George 92]
George, J.F., "The Conceptualization and Development of Organization Decision Support Systems", Journal of Management Information Systems, Vol. 8, No. 3, pp 109-125, 1992.

[Georgeff & Lansky 87]
Georgeff, M.P. and Lansky, A.L., "Reactive Reasoning and Planning", In Proceedings of AAAI'87, pp. 677-682, 1987.

[Gillan & McPherson 92]
Gillan, C., and McPherson, K., "White Paper: Executive Information Systems", Computer world, October 19, 1992.

[Glass 92]
Glass, Robert L., "A Comparative Analysis of the Topic Areas of Computer Science, Software Engineering, and Information Systems", Journal of Systems Software, Vol. 19, pp.277-289, 1992.

[Glover et al 92]
Glover, H, Watson, H.J., and Rainer, R.K., Jr., "20 Ways to Waste an EIS Investment", Information Strategy: The Executive's Journal, Vol.8, No. 2, pp. 11-17, 1992.

[Godefroid & Kabanza 91]
Godefroid, P. and Kabanza, F., "An Efficient Reactive Planner for Synthesizing Reactive Plans", Proceedings of ABBE, pp. 640-645, 1991.

[Goldberg & Robson 83]
Goldberg, A., and Robson, D., Smalltalk-80: The Language and its Implementation, Reading, Mass: Addison-Wesley, 1983.

[Gorry & Scott Morton 89]
Gorry, G.A., and Scott Morton, M.S., "A Framework for Management Information Systems", Sloan Management Review, 30, 3, pp.49-61, 1989.

[Green 91]
Green, G.I., "Beyond Information Technologies: Organizational Intelligence Services", Proceedings of the 24th Annual Hawaii International Conference on Systems Sciences, Vol IV, Organizational Systems and Technology Track, pp. 38-47, 1991.

[Guimaraes 91]
Nuno Guimaraes, AT&T Bell Laboratories, Building Generic User Interface Tools: an

Experience with Multiple Inheritance, OOPSLA '91 Conference Proceedings, ACM SIGPLAN, pp 89-96, 1991.

[Haas 92]
Haas, A.R., "A Reactive Planner that uses Explanation Closure", Principles of Knowledge Representation and Reasoning: Proceedings of the Third International Conference (KR'92), pp. 93-102, 1992.

[Hammer 90]
Hammer, M., "Reengineering Work: Don't Automate, Obliterate", Harvard Business Review, July-August, pp.104-112, 1990.

[Hammer & Champy 93]
Hammer, M., and Champy, J., Re-engineering the Corporation: A Manifesto for Business Revolution, Harper Business, New York, 1993.

[Hatley & Pirbhai 87]
Hatley, D.J., and Pirbhai, I.A., Strategies for Real-Time Systems Specification, Prentice Hall, Englewood Cliffs, N.J., 1987.

[Head 82]
Head, Robert V., Strategic Planning for Information Systems, , 1982.

[Heany 89]
Heany, D.F., "Cut Throat Team Mates: Achieving Effectiveness in Teamwork among Professionals", Dow Jones-Irwin, Homewood, IL., 1989.

[Hedberg & Jönsson 82]
Hedberg, H. and Jönsson, S., "Designing Semiconfusing Information Systems for Changing Organizations", Data Base, Vol 13, No. 2 & 3, pp. 12-25, Winter 1982.

[Hedberg 81]
Hedberg, B, "How Organization Learn and Unlearn", Handbook of Organizational Design, P. Nystrom and W. Starbuck (editors), Oxford University Press, New York, pp. 1-27, 1981.

[Hosmer 82]
Hosmer, L.T., Strategic Management: Text and Cases on Business Policy, Prentice-Hall, Inc. Englewood Cliffs, New Jersey 07632, 1982.

[Huber 91]
Huber, G.P., "Organization Learning: The Contributing Processes and the Literatures", Organizational Science, Vol 2, No. 1, pp.88-115, 1991.

[Hufnagel 87]
Hufnagel, E.M., "Information Systems Planning: Lessons From Strategic Planning", Information and Management, 12, pp.263-270, 1987.

[ICL 93]
ICL, Business Modellers Workbench User Guide, Issue 2.0, January 1993.

[IT 94]
Interfacing Technologies, Enterprise Modelling System (EMS) User Tutorial, Version 0.1,1994.

[ITRI 92]
Information Technology Research Institute Business Plan, Department of Computing Science, University of Alberta, July 1992.

[Jain 95]
Jain, S., "Data Warehouse can Help", Computing Canada, Vol. 21, Iss. 7, pp.34, March 29, 1995.

[Jarke 86]
Jarke, M., "Group Decision Support through Office Systems: Developments in Distributed DSS Technology", Decision Support Systems: A Decade in Perspective, E.R. McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North Holland), IFIP, pp. 145-128, 1986.

[Jones 92]
Jones, R.M., "Research and Development of a Method for Determining Strategic Information Needs of Manager", Computers and Industrial Engineering, Vol. 23, No. 1-4, pp. 475-478, 1992.

[Kaelbling 87]
Kaelbling, L.P., "An architecture for intelligent reactive systems", Reasoning about Actions and Plans: Proc. of the 1986 Workshop, Morgan Kaufmann, California, 1987.

[Kanal & Lemmer 86]
Kanal, L., and Lemmer, J., Uncertainty in Artificial Intelligence, Amsterdam: North Holland, 1986.

[Karimi & Konsynski 91]
Karimi, J. and Knosynski, B.R., "Globalization and Information Management Strategies", Journal of Management Information Systems, Vol. 7, No. 4, pp.7-26, Spring 1991.

[Keen 86]
Keen, P.G.W., "Decision Support Systems: The Next Decade", Decision Support Systems:

A Decade in Perspective, E.R. McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North Holland), IFIP, 1986.

[Keen & Scott Morton 78]
Keen, P.G.W., and Scott Morton, M.S., Decision Support Systems: an Organizational Perspective, Addison-Wesley, 1978.

[Kent 90]
Kent, A., "EIS: The Practice", Australian Accountant, pp. 51-53, October 1990.

[Kindel 93]
Kindel, S., "Automating the Numbers", Financial World, pp. 64-65, February 16, 1993.

[King 78]
King, W.R., Strategic Planning for Information Systems, MIS Quarterly, 2, 1, pp. 27-37, March 1978.

[Kinlan 92]
Kinlan, J., "EIS Moves to the Desktop", Byte, pp. 206 -214, June 1992.

[Kumar & Vrat 89]
Kumar, R. and Vrat, P., "Using Computer Models in Corporate Planning", Long Range Planning, Vol. 22, No. 2, pp.114-120, 1989.

[Kunz et al 84]
Kunz, J.C., Kelhr, T.P., and William, M.D., "Applications Development Using a Hybrid AI Development System", AI Magazine, Fall 1984, pp. 41-45.

[Laird & Rosenbloom 90]
Laird, J.E. and Rosenbloom, P.S., "Integrating Planning, Execution, and Learning in Soar for External Environments", Proceedings of AAAI'90, 1990.

[Langer et al 94]
Langer, D., Rosenblatt, J.K., and Hebert, M., "An Integrated System for Autonomous Off-road Navigation, Proceedings. IEEE International Conference on Robotics and Automation, vol. 1, pp. 414-419 , 1994.

[Larichev & Petrovsky 88]
Larichev, O.I. and Petrovsky, A.B., "Decision Support Systems for Ill-structured Problems: Requirements and Constraints", Organization Decision Support Systems, edited by R.M.Lee, A.M. McCosh and P. Migiliarese, Elsevier Science Publishers B.V., North-Holland, IFIP, 1988.

[Law 88]
Law, M.H., Guide To Information Resource Dictionary systems applications: General Concepts and Strategic Systems Planning, NBS Special Publication 500-152, National Institute of Standards and Technology, Gaithersburg, MD,, April 1988.

[Lederer & Sethi 92]
Lederer, A.L. and Sethi, V., "Root Causes of Strategic Information Systems Planning Implementation Problems", Journal of Management Information Systems, Vol.9, No.1, pp.25-45, Summer 1992.

[Lederer & Sethi 88]
Lederer A.L., and Sethi, V., "The Implementation of Strategic Information Systems Planning Methodologies", MIS Quarterly, pp. 445-461, September 1988.

[Lee & Leifer 92]
Lee, S., and Leifer, R.P., "A Framework for Linking the Structure of Information Systems with Organization Requirements for Information Sharing", Journal of Management Information Systems, Vol. 8, No. 4, pp. 27-44, 1992.

[Levesque et al 91]
Levesque, G., Nguyen, C.L., and Sheehy, G., "Modelling and Design of a Strategic Information System: a Cognitive and Object Oriented Approach", Proceedings of the International Symposium on Artificial Intelligence, Editorial Limusa, Mexico City, Mexico, pp.509-515, November 1991.

[Levitt & March 88]
Levitt, B., and March, J.G., "Organizational Learning", Annual Review of Sociology, Vol. 14, pp. 319-340, 1988.

[Lopez 93]
Lopez, B., "Reactive Planning through the Integration of a Case-Based System and a Rule-Based System", Proceedings of AISB93, Ninth Biennial Conference of the Society for the Study of Artificial Intelligence and the Simulation of Behaviour, pp. 189-198, 1993.

[Lyytinen 87]
Lyytinen, Kalle, Different Perspectives on Information Systems: Problems and Solutions, ACM Computing Surveys, Volume 19, Number 1, pp. 5 - 46., March 1987.

[Maglitta 93]
Maglitta, J., "Squeeze Play", Computerworld, Vol 27, No. 16, pp. 86-91, 1993.

[Makowski & Sawaragi 91]
Makowski, M., and Sawaragi, Y., "Advances in Methodology and Applications of

decision Support Systems", Collaborative Papers, International Institute fro Applied Systems Analysis, Luxemberg, Austria, December 1991.

[March 91]
March, J.G., "Exploration and Exploitation in Organization Learning", Organization Science, Vol 2, No. 1, pp. 71-87, 1991.

[Marcus & Robey 88]
Marcus, M.L. and Robey, D., "Information Technology and Orgnaizational Change: Causal Structure in Theory and Research", Management Science, Vol. 34, No. 5, pp.583-598., May 1988.

[Martin 87]
Martin, J., Information Engineering, Volumes 1,2, and 3. Savant Research Studies, 1987.

[Marx 91]
Marx, G.T., "The Case of the Omniscient Organization", The Information Infrastructure, Harvard Business Review Book Series, pp. 109-117, 1991.

[McLean & Sol 86]
McLean, E.R., and Sol, H.G., Decision Support Systems: A Decade in Perspective. Proceedings of the IFIP WG 8.3 Working Conference, North-Holland, Amsterdam, Netherlands, 1986.

[McMenamin & Palmer 84]
McMenamin, S.M., and Palmer, J.F., Essential Systems Analysis, Yourdon Press, New York, 1984.

[Miller 93]
Miller, D., "The Architecture of Simplicity", Academy of Management Review Vol 18, No. 1, pp. 116-138, 1993.

[Miller et al 93]
Muller, H.A., Tilley, S.R., Orgun, M.A., Corrie, B.D., and Madhavji, N.H., "A Reverse Engineering Environment Based on Spatial and Visual Software Interconnection Models", 1993, reverse engineering.

[Mintzberg 73]
Mintzberg, H., The Nature of Managerial Work, New York: Harper & Row, 1973.

[Mintzberg 78]
Mintzberg, H., Patterns in Strategy Formulation, Managment Science, pp. 934-948, 1978.

[Mintzberg et al 76]
Mintzberg, H., Raisinghani, D., and Theoret, A., "The Structure of 'Unstructured' Decision Processes", Administrative Science Quarterly, Volume 21, June 1976.

[Mintzberg & Quinn 91]
Mintzberg, H. and Quinn, J.B., The Strategy Process: Concepts, Contexts, Cases, Prentice Hall, Englewood Cliffs, New Jersey 07632, 1991.

[Mitchell 90]
Mitchell, T.M., "Becoming Increasingly Reactive", Proceedings of AAAI'90, pp. 1051-1058, 1990.

[Miura et al 93]
Miura, J., Shimoyama, I., and Miura, H., "Integration of Problem-solving and Learning in Intelligent Robots", Advanced Robotics, Vol. 7, Iss.4, pp. 309-328, 1993.

[Morin & Chustas 95]
Morin, M. and Chustas, A., "BPR: An Over-abused Term", Computing Canada, Vol. 21, Iss. 7, pp.36, March 29, 1995.

[Morrison & Weiser 94]
Morrison, J and Weiser, M., "An Object-Oriented Model to Aid Organizational Decision Making and Learning", Proceedings of the Twenty-Seventh Annual Hawaii International Conference on Systems Sciences, 1994.

[Neuron Data 87]
Neuron Data Inc., NEXPERT OBJECT: An Expert System on VAXStation under VMS, 1987.

[Nilsson 84]
Nilsson, N.J., Shakey, the Robot, Technical Note 323, Artificial Intelligence Centre, SRI International, California, 1984.

[Nunamaker 91]
Nunamaker, J.F. Jr., "Management Information Systems", Journal of Management Information Systems, Vol. 7, No. 4, editorial comments, Spring 1991.

[Nunamaker et al 89]
Nunamaker, J.F. Jr., Weber, E.S., and Chen, M., "Organizational Crisis Management Systems: Planning for Intelligent Action", Journal of Management Information Systems, Vol. 5, No. 4, pp. 8-32, Spring 1989.

[Nunamaker et al 91]
Nunamaker, J.F. Jr., Chen, M. and Purdin, T.D.M., "Systems Development in Information

Systems Research", Journal of Management Information Systems, Winter 1990/91, Vol 7, No. 3, pp. 89 - 106, 1990/91.

[Oivo & Basili 92]
Oivo, M. and Basili, V.R. , "Representing Software Engineering Models: The TAME Goal Oriented Approach", IEEE Transactions on Software Engineering, Vol 18, No. 10, October 1992.

[Ojha & Brown 93]
Ojha, A.K. and Brown, J.L., "Organizational Theory as a Guide to Computer Applications in Decision Making", Unpublished paper, Department of Organizational Analysis, Faculty of Business, University of Aiberta, ?.

[Parsaye & Chignell 88]
Parsaye, K., and Chignell, M., Expert Systems, New York: John Wiley & Sons, 1988.

[Patching 94]
Patching, David, Business Process Re-engineering, Management Services, Vol 38, Iss. 6, pp.10-13, June 1994.

[Patching 95a]
Patching, D., "Business Process Re-engineering: Reading between the Lines", Management Services, Vol 39, Iss. 2, pp. 14-17, Feb. 1995.

[Patching 95b]
Patching, D., "Business Process Re-engineering", Management Services, Vol 39, Iss. 4, pp. 8-11, April 1995.

[Pohl & Jarke 92]
Pohl, K. and Jarke, M., Quality Information Systems: Repository Support for Evolving Process Models, Informatik V, RWTH Aachen, Ahornstr. 55, 5100 Aachen, Germany, No. 92-37, 1992.

[Porter 85]
Porter, M., Competitive Strategy, New York, Free Press, 1985.

[Prosser 89]
Prosser, P., "A Reactive Scheduling Agent", Proceedings of IJCAI - 89, pp. 1004- 1009, 1989.

[Revenaugh 94]
Revenaugh, D. Lance, Business Process Re-engineering: The Unavoidable Challenge, Management Decision, Vol 32, Iss. 7, pp. 16-27, 1994.

[Rockart 79]
Rockart, J.F., "Chief Executives Define Their Own Data Needs", Harvard Business Review 57(2), pp.81-93, 1979.

[Rockart 82]
Rockart, J.F., "The changing role of the Information Systems Executives: A Critical Success Factors Perspective", Sloan Management Review 24(1), pp.3-13, 1982.

[Rockart & DeLong 88]
Rockary, J.F., and DeLong, D.W., Executive Support Systems: The Emergence of Top Management Computer Use, Homewood, II: Dow Jones-Irwin, 1988.

[Rockart & Scott Morton 84]
Rockart, J.F., and Scott Morton, M.S., "Implications of Changes in Information Technology for Corporate Strategy", Interfaces, Vol 14, Iss. 1, pp. 84-95, 1984.

[Rosen & Law 89]
Rosen, B.K. and Law, M.H., Guide to Data Administration, NIST Special Publication 500-173, National Institute of Standards and Technology, Gaithersburg, MD, October, 1989.

[Rumelhart 80]
Rumelhart, D.E., "Schemata: The Building Blocks of Cognition", Theoretical Issues in Reading Comprehension, R.Spiro, B.C. Bruce and W.F. Brewer (editors), Hillsdale, N.J.: Lawrence Erlbaum Associates, 1980.

[Rumelt 91]
Rumelt, R.P., "How Much Does Industry Matter?", Strategic Management Journal, pp. 167-186, 1991.

[Saaty 80]
Saaty, T.L., The Analytic Hierarchy Process, New York: McGraw-Hill, 1980.

[Sahota 93]
Sahota, M.K., Real-Time Intelligent Behaviour in Dynamic Environments: Soccer-playing Robots, M.Sc. Thesis, University of British Columbia, 1993.

[Sahota 94]
Sahota, M.K., Reactive Deliberation: An Architecture for Real-Time Intelligent Control in Dynamic Environments, Proceedings, AAAI'94, 1994.

[Sanders 92]
Sanders, D.F., "Determining Information Requirements of Senior Management: towards a Methodology", Canadian Journal of Information Science. Vol. 17, No. 1. pp.1-23, April

1992.

[Segre 88]
Segre, A.M., Machine Learning of Robot Assembly Plans, Kluwer Academic Press, 1988.

[Shlaer & Mellor 92]
Shlaer, S., and Mellor, S.J., Object Lifecycles: Modelling the World in States, Englewood Cliffs, New Jersey: Yourdon Press, 1992.

[Shu 90]
Shu, H., "Planning with Reactivity", Artificial Intelligence in the Pacific Rim. Proceedings of the Pacific Rim International Conference on Artificial Intelligence, pp. 681-686, 1990.

[Silver 88]
Silver, M.S., "On the Restrictiveness of Decision Support Systems", Organization Decision Support Systems, edited by R.M .Lee, A.M. McCosh and P. Migiliarese, Elsevier Science Publishers B.V., North-Holland, IFIP, pp 259-270, 1988.

[Simon 60]
Simon, H.A., The New Science of management Decision, Harper and Row, New York, New York, 1960.

[Smolander et al 91]
Smolander, K., Lyytinen, K., Tahvanainen, V.P., and Marttiin, P., "MetaEdit - A Flexible Graphical Environment for methodology Modelling", Advanced Information Systems Engineering, Springer-Verlag, Berlin, Germany, 1991.

[Sorenson et al 88]
Sorenson, P.G., Tremblay, J.P., and McAllister, A.J., "The metaview System for Many Specification Environment", IEEE Software, pp. 30-38, March 1988.

[Sprague 86]
Sprague, Ralph H., Jr., "DSS in Context", Decision Support Systems: A Decade in Perspective, E.R.McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North-Holland), IFIP, pp.19-24, 1986.

[Stabell 86]
Stabell, C.B., "Decision Support Systems: Alternative Perspectives and Schools", Decision Support Systems: A Decade in Perspective, E.R. McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North Holland), IFIP, pp. 173-182, 1986.

[Stata 89]
Stata, R., "Organizational Learning - The Key to Management Innovation", Sloan Management Review, pp. 63-74, Spring 1989.

[Stein & Zwass 94]
Stein, E.W., and Zwass, V., "Actualizing Organizational Memory with Information Systems", Information Systems Research, Vol. 6, No. 1, 1995.

[Stein 95]
Stein, E.W., "Organizational Memory: Review of Concpets and Recommendations for Management", International Journal of Information Management, Vol. 15, No. 1, 1995,
.

[Teory et al 86]
Teory, T.J., Yang, D., and Fry, J.P., "A Logical Design Methodology for Relational Database Using the Extended Entity-relationship Model", ACM Computing Surveys, Vol. 18, No. 2, pp.196-222, 1996.

[Thierauf 91]
Thierauf, R,J., Executive Information Systems:A Guide for senior Management and MIS Professionals, Quorum Books, Westport, CT, USA, 1991.

[Thomas & McDaniel 90]
Thomas, J.B., and McDaniel, R.R., "Interpreting Strategic Issues: Effects of Strategy and the Information Processing Structure of Top Management Teams", Academy of Management Journal, Vol. 33, No. 2, pp. 286-306, 1990.

[TI 93]
Texas Instruments, Business Design Facility Tutorial, , May 1993.

[Tilley 93]
Tilley, S.R., "Management Decision Support Through Reverse Engineering Technology", Unpublished paper, Department of Computing Science, University of Victoria, Victoria, Canada, 1993.

[Tobin 90]
Tobin, L. M., "The New Quality Landscape: Total Quality Management, Journal of Systems Management, pp. 10-14, November 1990.

[Todd & Benbasat 92]
Todd, P., and Benbasat, I., "The Use of Information in Decision Making: An Experimental Investigation of the Impact of Computer-Based Decision Aids", MIS Quarterly, pp.373-393, 1992.

[Traverso et al 94]
Traverso, P., Cimatti, A., Spalazzi, L., Armando, and A., Giunchiglia, E., "MRG: Building Planners for Real-world Complex Applications", Applied Artificial Intelligence, Vol. 8, Iss. 3, pp. 333-357, 1994.

[Trippi & Salameh 89]
Trippi, R.R., and Salameh, T.T., "Strategic Information Systems: Current Research Issues", Information Systems Management, Vol. 6, No. 3, pp. 30-35, 1989.

[Turban 93]
Turban, E., Decision Support and Expert Systems: Management Information Systems, MacMillan Publishing Company, New York, 1993.

[Vandenbosch 94]
Vandenbosch, B., Executive Support System Impact Viewed from a Learning Perspective, Research Report, Weatherhead School of Management, Case Western Reserve University, Cleveland, Ohio, 1994.

[Vella 90]
Vella, P., "EIS: The Theory", Australian Accountant, pp. 49-50, October 1990.

[Vercelli et al]
Vercelli, G., Giuffrida, F., Rolla, A., Toracca, and R. Morasso, P., "NAVNEX: a Hybrid System which Learns Navigation Situations in Real Time", Proceedings. Sixth International Conference on Tools with Artificial Intelligence, pp. 832-835, 1994.

[Vina & Dominguez 92]
Vina, A., and Dominguez, J.M., "Reactive Process Control Using a Blackboard Architecture", Artificial Intelligence in Real Time Control 1992. Selected papers from the IFAC/IFIP/IMACS Symposium, pp. 423-430, 1992.

[Volonino & Watson 91]
Volonino, Linda and Watson, Hugh J., "The Strategic Business Objectives Method for Guiding Executive Information Systems Development", Journal of Management Information Systems, Winter 1990/91, Vol. 7, No. 3, pp.27-39, 1990/91.

[Walsh & Ungson 91]
Walsh, J P., and Ungson, G.R., "Organizational Memory", Academy of Management Journal, Vol 16, No. 1, pp. 57-91, 1991.

[Walsh 88]
Walsh, J P., "Selectivity and Selective Perception: An Investigation of Manager's Belief Structures and Information Processing", Academy of Management Journal, Vol 31, No. 4, pp.873-896, 1988.

[Ward & Mellor 85]
Ward, P.T., and Mellor, S.J., Structured Development for Real-Time Systems, Vol. 1, 2 and 3, Yourdon Press Computing Series, Prentice-Hall, Englewood Cliffs, NJ, 1985.

[Ward et al 90]
Ward, J.M., Griffiths, P., and Whitmore, P., Strategic Planning for Information Systems, John Wiley & Sons, England, 1990.

[Watson et al 91]
Watson, H.J., Rainer, R.K. Jr., and Koh, C.E., "Executive Information Systems: A Framework for Development and a Survey of Current Practices", MIS Quarterly, pp. 13-30, March 1991.

[Watterson 94]
Watterson, K., "The Changing World of EIS", BYTE Magazine, pp. 183-193, June 1994.

[Weber & Konsynski 87]
Weber, E.S. and Konsynski, B.R., "Problem Management: Neglected Elements in Decision Support Systems", Journal of Management Information Systems, Vol. 4, No. 3, 1987/88.

[Witte 72]
Witte, E., "Field Research on Complex Decision-Making Processes - the Phase Theorem", International Studies of Management and Organization, pp. 156-182, 1972.

[Yadav & Khazanchi 92]
Yadav, S.B., and Khazanchi, D., "Subjective Understanding in Strategic Decision Making: an Information Systems Perspective", Journal of Decision Support Systems, Vol.8, No.1, pp.55-71., January 1992.

[Young 87]
Young, Y.F., "A Systems Architecture for Supporting Senior Managers' Messy Tasks", Journal of Information and Management. Vol.13, No. 2, pp.85-94., September 1987.

[Yourdon & Constantine 78]
Yourdon, E., and Constantine, L.L., Structured design, 2nd edition, Yourdon Press, New York, 1978.

[Yu 93]
Yu, E.S.K., "An Organization Modelling Framework for Multi-Perspective Information System Design", Technical Report, DKBS-TR-93-2, Department of Computer Science, University of Toronto, 1993

[Yuen et al 92]
Yuen, H.S., Ho, S., Zeleznikow, J., "Adding Qualitative Reasoning to an organizational database for Management Decision Support", Next Generation of Information Systems: From Data to Knowledge. A Selection of Papers Presented at two IJCAI-91 Workshops, pp.79-103, Spronger-Verlag, Berlin, Germany., 1992.

[Zaniolo et al 86]
Zaniolo, C., et al, "Object Oriented Database Systems and Knowledge Systems", in Expert Database Systems, edited by Kersschberg, L., The benjamin/Cummings Publishing Company, Inc., 1986.

[Zelinsky & Yuta 93]
Zelinsky, A., and Yuta, S., "Reactive Planning for Mobile Robots using Numeric Potential Fields", Intelligent Autonomous Systems, IAS-3, Proceedings of the International Conference, pp. 84-93, 1993.

[Zmud 86]
Zmud, R.W., "Supporting Senior Executives through Decision Support Technologies: A Review and Directions for Future Research", Decision Support Systems: A Decade in Perspective, E.R. McLean, H.G. Sol (editors), Elsevier Science Publishers B.V. (North Holland), IFIP, pp. 87-101, 1986.

[Zviran 90]
Zviran, Moshe, "Relationships between Organizational and Information Systems Objectives: Some Empirical Evidence", Journal of Management Information Systems, M.E.Sharpe, Inc., Vol. 7, No. 1, Summer 1990.

Appendix A: Details of the Information Technology Research Institute

Goal name	Description	Priority
Goal1	To support industry in maximizing their return on information technology investments, through technology transfer programs such as collaborative research projects, specialized training programs and technology consultation.	4
Goal2	To explore interesting and challenging applied research ideas and problems in information technology by examining complex real-life problems and using actual data and parameters in research experiments and prototypes.	3
Goal3	To promote collaborative efforts amongst different University disciplines and provide a multi-disciplinary approach to information technology solutions.	1
Goal4	To participate, together with other organizations, in establishing a world-class information technology research and development infrastructure in Alberta	2
Goal5	To expand and strengthen the Department's research infrastructure and facilities	1
Goal6	To operate the Information Technology Institute in a self-supporting mode.	5

Table A-1 Goals of the Information Technology Research Institute

Note: Goal 1 to 5 are taken directly from the ITRI Business Plan document. Goal 6 is added as part of the prototyping process.

CSF name	Description
CSF1	Collaborative Research with Industry
CSF2	Corporate-sponsored student projects/theses
CSF3	Research Publications and Dissemination Infrastructure
CSF4	Technology Training Program
CSF5	Technology Consultation Program
CSF6	Research and Industry Presentation/Workshop
CSF7	Short-term Industrial/Research Exchange Program
CSF8	Alberta Research and Development Electronic Network
CSF9	IT Research and Development Online Database
CSF10	IT Forecast Program
CSF11	Corporate Membership
CSF12	ITRI Administration

Table A-2 CSFs of the Information Technology Research Institute

Note: CSF 1 to 10 are taken directly from the ITRI Business Plan. CSF 11 and 12 are added during the prototpying process

CSF \ Goal		Goal1	Goal2	Goal3	Goal4	Goal5	Goal6
CSF1	Collaborative Research with Industry	0.45	0.4	0 3	0.05	0.2	0.2
CSF2	Corporate-sponsored Student Projects/Theses	0.05	0.1	0.2	0.05	0.15	
CSF3	Research Publication and Dissemination	0.05	0.1	0.3	0.2	0.15	
CSF4	Technology Training Program	0.2					0.2
CSF5	Technology Consultation Program	0.1					0.1
CSF6	Research/Industry Presentation and Workshop		0.1		0.1		
CSF7	Industrial/Research Exchange Program		0.2		0.1	0.15	
CSF8	Alberta R&D Electronic Network	0.05		0.1	0.2	0.15	0.05
CSF9	IT R&D Online Database	0.05	0.05		0.2	0.1	0.05
CSF10	IT Forecast Program	0.05	0.05	0.1	0.1	0.1	
CSF11	Corporate Membership						0.2
CSF12	ITRI Administration						0.2

Table A-3 Correlation Matrix between the ITRI Goals and CSFs
(based on original document)

CSF \ Goal		Goal1	Goal2	Goai3	Goal4	Goal5	Goal6
CSF1	Collaborative Research with Industry	0.45	0.4	0.1		0.2	0.2
CSF2	Corporate-sponsored Student Projects/Theses	0.05	0.2	0.1		0.1	
CSF3	Research Publication and Dissemination	0.05			0.2	0.1	
CSF4	Technology Training Program	0.2					0.2
CSF5	Technology Consultation Program	0.1	0.1				0.1
CSF6	Research/Industry Presentation and Workshop		0.1		0.2	0.1	
CSF7	Industrial/Research Exchange Program		0.2	0.2	0.2	0.2	
CSF8	Alberta R&D Electronic Network	0.05		0.2	0.1	0.1	
CSF9	IT R&D Online Database	0.05		0.2	0.1	0.1	
CSF10	IT Forecast Program	0.05		0.2	0.2	0.1	
CSF11	Corporate Membership						0.2
CSF12	ITRI Administration						0.3

Table A-4 Correlation Matrix between the ITRI Goals and CSFs
(updated during the prototyping process)

Performance Indicators for the CSFs		Year 1	Year 2	Year 3	Year 4	Year 5
Perf1.	Total Revenue from Collaborative Research Program			$500K	$1000K	$1000K
Perf2.	Program Evaluation Index for Collaborative Research Program			3.5	3.5	3.5
Perf3.	No. of Corporate-sponsored Student projects/theses		5	10	15	15
Perf4.	Program Evaluation Index for Corporate-sponsored Student project/theses Program		3.5	3.5	3.5	3.5
Perf5.	Number of Subscriptions		50	100	150	200
Perf6.	Total Revenue from Technology Training Program	$30K	$120K	$120K	$120K	$120K
Perf7.	Program Evaluation Index for Technology Training Program	3.5	3.5	3.5	3.5	3.5
Perf8.	Total Revenue from Technology Consultation Program		$45K	$60K	$60K	$60K
Perf9	Program Evaluation Index for Technology Consultation Program		3.5	3.5	3.5	3.5
Perf10	No. of attendants for R/I Presentations and Workshops	25	40	50	50	50
Perf11	Program Evaluation Index for R/I Presentations/Workshops	3.5	3.5	3.5	3.5	3.5
Perf12	Percentage of I/R Exchange Application filled				50%	75%
Perf13	Program Evaluation Index of I/R Exchange Program				3.5	3.5
Perf14	Program Evaluation Index of Alberta R&D Electronic Network			3.5	3.5	3.5
Perf15	Program Evaluation Index of IT R&D Online Database			3.5	3.5	3.5
Perf16	Program Evaluation Index of IT Forecast Program			3.5	3.5	3.5
Perf17	Total Amount of Corporate membership Fees	$30K	$65K	$105K	$135K	$135K
Perf18	Program Evaluation Index of Corporate Membership Program	3.5	3.5	3.5	3.5	3.5
Perf19	Ratio of ITRI Revenue/Expenditure	< 1	< 1	1	1	1

Table A-5 Performance Indicators for the ITRI CSFs

Note: Performance Indicators 1 to 16 are taken directly from the ITRI Business Plan. Performance Indicators 17 to 19 are added during the prototyping process.

	CSF1	CSF2	CSF3	CSF4	CSF5	CSF6	CSF7	CSF8	CSF9	CSF10	CSF11	CSF12
Perf1	X											
Perf2	X										X	
Perf3		X										
Perf4		X									X	
Perf5			X									
Perf6				X								
Perf7				X							X	
Perf8					X							
Perf9					X						X	
Perf10						X						
Perf11						X					X	
Perf12							X					
Perf13							X				X	
Perf14								X			X	
Perf15									X		X	
Perf16										X	X	
Perf17											X	
Perf18											X	
Perf19												X

Table A-6 Correlation Matrix between the ITRI CSFs and Performance Indicators

Objective	Description	earliest start date	latest completion date
Obj1	Establishment of Support Structure for Collaborative Research Program to meet the following expectations: Administrative Cost of program = 90% of Gross Revenue of program, Meet University Intellectual Property Guidelines.	Year 2	Year 2 Quarter 4
Obj2	Pre-Program Promotion to reach all Alberta Companies with IS Budget over $500K (estimate 100 companies)	Year 2	Year 2 Quarter 4
Obj3	Attaining Gross Revenue of $500K for the Collaborative Research Program during Year 3	Year 3	Year 3 Quarter 4
Obj4	Attaining Gross Revenue of $1000K for the Collaborative Research Program during Year 4	Year 4	Year 4 Quarter 4
Obj5	Maintaining Gross Revenue of $1000K for the Collaborative Research Program during Year 5	Year 5	Year 5 Quarter 4
Obj6	Establishment of Policies and Procedures for the Collaborative Research program to meet the following expectations: Administrative Cost of program = 90% of Gross Revenue of program, Meet University Intellectual Property Guidelines.	Year 2	Year 2 Quarter 4
Obj7	Establishment of Expertise to Support Canadian Companies to seek Collaborative Research Grants within Canada	Year 2 Quarter 1	Year 2 Quarter 3
Obj8	Submission of 20 Collaborative Research Applications in Year 3	Year 3	Year 3 Quarter 2
Obj9	Signing 10 Collaborative Research Contracts in Year 3	Year 3	Year 3 Quarter 4
Obj10	Promotion to reach all Canadian Companies with IS budget over $500K (estimate 500 companies)	Year 4	Year 4 Quarter 1

Table A-7 Objectives for Accomplishing the Collaborative Research CSF
(Page 1 of 2)

Objective	Description	earliest start date	latest completion date
Obj11	Submission of 20 new Collaborative Research Application in Year 4	Year 4	Year 4 Quarter 2
Obj12	Signing 10 new Collaborative Research Contracts in Year 4	Year 4	Year 4 Quarter 4
Obj13	Submission of 20 new Collaborative Research Applications in Year 5	Year 5	Year 5 Quarter 2
Obj14	Signing 10 new Collaborative Research Contracts in Year 5	Year 5	Year 5 Quarter 4
Obj15	In-depth Exploration of 30 Collaborative Research Opportunities	Year 5	Year 5 Quarter 2
Obj16	Preparation of 20 Collaborative Research Applications	Year 5	Year 5 Quarter 2
Obj17	Follow up of 50 Collaborative Research Opportunities	Year 3	Year 3 Quarter 2
Obj18	In-depth Exploration of 25 Collaborative Research Opportunities	Year 3	Year 3 Quarter 2
Obj19	Preparation of 20 Collaborative Research Applications	Year 3	Year 3 Quarter 2
Obj20	In-depth exploration of 30 Collaborative Opportunities	Year 4	Year 4 Quarter 2
Obj21	Preparation of 20 Collaborative Research application	Year 4	Year 4 Quarter 2

Table A-7 Objectives for Accomplishing the Collaborative Research CSF (Page 2 of 2)

Action Plan	Description	Duration	Resource Required	Amount of Resource
AP1	Adopt IPO Policies and Procedures for Collaborative research	2 months	Director P. Admin. Secretary	0.1 mm 0.25 mm 0.2 mm
AP2	Obtain Department Approval for Draft Policies and Procedures of Collaborative Research Program	2 months	Director P. Admin.	0.2 mm 0.2 mm
AP3	Obtain University Approval for Draft Policies and Procedures of the Collaborative Research Program	2 months	Director	0.1 mm
AP4	Implement Policies and Procedures of the Collaborative Research Program	3 months	Director P. Admin.	0.1 mm 0.1 mm
AP5	Custom Develop Policies and Procedures of the Collaborative Research Program based on faculty input	3 months	Director P. Admin. Secretary	0.25 mm 0.75 mm 0.5 mm
AP6	Obtain Department Approval for Draft Custom Policies and Procedures of the Collaborative Research program	1 months	Director P. Admin.	0.1 mm 0.1 mm
AP7	Obtain University Approval for Draft Custom Policies and Procedures of the Collaborative Research Program	2 months	Director P. Admin.	0.1 mm 0.2 mm
AP8	Collect Resource Material for Collaborative Research Program Funding	6 months	P. Admin. Secretary	0.25 mm 0.5 mm
AP9	Develop Consulting Support for Collaboration Research Program Funding Application	2 months	P. Admin.	0.5 mm
AP10	Develop Printed Promotion Material for the Collaborative Research Program	1 month	P. Admin. Secretary	0.1 mm 0.2 mm

Table A-8 Action Plans for Accomplishing the Collaborative Research CSF (Page 1 of 3)

Action Plan	Description	Duration	Resource Required	Amount of Resource
AP11	Mail Printed Promotion Material for Collaborative Research Program within Alberta	1 month	secretary	0.1 mm
AP12	Develop Promotion Presentation for Collaborative research Program	1 month	Director P. Admin. Secretary	0.1 mm 0.2 mm 0.1 mm
AP13	Conduct General Promotion Presentation for Collaborative Research Program	3 months	Director P. Admin.	0.2 mm 0.2 mm
AP14	Contact All Companies which expressed interest during Collaborative research Promotion Presentation	6 months	Director P. Admin.	0.3 mm 0.6 mm
AP15	Contact All Current Industrial Partners on Department File	4 months	Director P. Admin.	0.3 mm 0.3 mm
AP16	Explore detail of Collaborative research Proposals with Potential Clients	4 months	Director P. Admin.	0.5 mm 1 mm
AP17	Prepare 20 Collaborative research Applications	2 months	Director P. Admin. Secretary	0.1 mm 0.1 mm 0.3 mm
AP18	Assist Companies to Prepare 20 Collaborative Research Applications	2 months	Director P. Admin.	0.1 mm 0.1 mm
AP19	Implement Admininistration and Project Support for 10 Collaborative Research projects	2 months	Director P. Admin. Secretary	0.1 mm 0.3 mm 0.1 mm
AP20	Mass Mailing of Promotion material within Canada	3 months	Secretary	0.1 mm

Table A-8 Action Plans for Accomplishing the Collaborative Research CSF (Page 2 of 3)

Action Plan	Description	Duration	Resource Required	Amount of Resource
AP21	Conduct General Promotion Presentation to all Companies in Western Canada	3 months	Director P. Admin.	0.2 mm 0.4 mm
AP22	Contact All Companies which expressed interest during Collaborative Research Promotion Presentation	6 months	Director P. Admin.	0.3 mm 0.6 mm
AP23	Explore detail of Collaborative research Proposals with Potential Clients	4 months	Director P. Admin.	0.5 mm 1 mm
AP24	Prepare 20 new Collaborative research Applications	2 months	P. Admin. Secretary	0.1 mm 0.3 mm
AP25	Assist Companies to Prepare 20 Collaborative Research Applications	2 months	P. Admin.	0.1 mm
AP26	Implement Admininistration and Project Support for 10 new Collaborative Research projects	2 months	P. Admin. Secretary	0.1 mm 0.05 mm
AP27	Explore detail of Collaborative research Proposals with Potential Clients	4 months	Director P. Admin.	0.5 mm 1 mm
AP28	Prepare 20 new Collaborative research Applications	2 months	P. Admin. Secretary	0.1 mm 0.3 mm
AP29	Assist Companies to Prepare 20 Collaborative Research Applications	2 months	P. Admin.	0.1 mm
AP30	Implement Admininistration and Project Support for 10 new Collaborative Research projects	2 months	P. Admin. Secretary	0.1 mm 0.05 mm

Table A-8 Action Plans for Accomplishing the Collaborative Research CSF (Page 3 of 3)

Appendix B: Smalltalk Implementation of the RCIM Object Types and Relationship Types

The RCIM Prototype is implemented using the Xerox ParcPlace VisualWorks/Smalltalk object-oriented programming environment. VisualWorks/Smalltalk is chosen because of its prototyping capability, its interactive and graphical interface, and its portability across multiple hardware and software platforms [Goldberg & Robson 89].

The conceptual design of the RCIM is based on an object-oriented approach. The choice of a pure object-oriented language like Smalltalk for the implementation of the prototype is therefore natural. However, much of the RCIM operation depends on the collaboration of objects related through the different Relationship Types. In this appendix, the Smalltalk implementation of the RCIM Object Types and Relationship Types is described to illustrate how multiple access paths are supported.

Implementation of the RCIM Object Types

Each RCIM Object Type is created as a Smalltalk class. Figure B-1 graphically illustrates the design of the *GOAL* Object Type as an example. A Smalltalk class called *Goal* is created for the *GOAL* Object Type. Each *GOAL* object (eg. **Goal1**, **Goal3**) is created as an instance of the *Goal* class. A class variable *ObjectList* is created in the *Goal* class to

keep track of all its instances. The unique name of the *GOAL* object is used as the key to locate the object from the *ObjectList*. Attributes of the RCIM Object Types are implemented as instance variables of the Smalltalk class and the behaviour of the objects are implemented using class or instance methods.

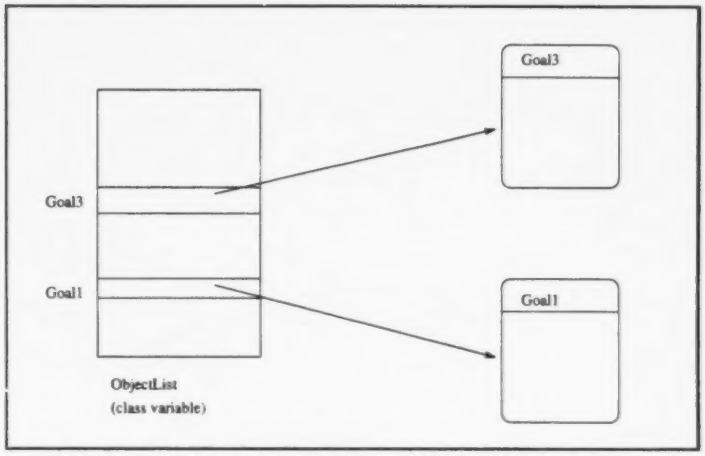

Figure B-1 Design of the *GOAL* Object Type

Implementation of the RCIM Relationship Types

The RCIM Relationship Types are designed to facilitate the different ways of retrieving the related objects. Each RCIM Relationship Type is created as a Smalltalk class. Several class variables are defined in each class to facilitate the different types of retrieval. The class variables vary for each class and are described separately.

A naming convention is used in the discussion of the RCIM Relationship Types. An "a" object refers to the first element of a binary relationship and the "b" object refers to the second element. For example, *CSF* and *OBJECTIVE* objects are the respective "a" and "b" objects in the *CSF_is_supported_by_OBJECTIVE* Relationship Type. An *AToBTable*

refers to a table linking the "a" objects to the "b" objects. Following the Smalltalk convention for variable names, class variables are denoted with the first character being capitalized, subsequent capitalized letters are used to aid readability of the names. For a three-party Relationship Type like the Monitor Relationship Type, the third party is referred to as the "c" object.

Support Relationship Type

There are four class variables in a Support Relationship Type, namely, the *RelationshipList*, the *AAlternativesTable*, the *AAlternativesToBTable*, and the *BToAAlternativesTable*. Figure B-2 illustrates the design of the variables in the Support Relationship Type.

A Support Relationship Type object is an instance of the Support Relationship Type. One Relationship Type object is created for each unique relationship that exists between two "a" and "b" objects. Access to the relationship can be accomplished via the class variable *RelationshipList*. The access key to the *RelationshipList* is the name of the relationship, ie. it is a compound key of the form (aName, altx, bName), made up of the name of the "a" object (aName), a unique number identifying a set of strategic alternatives of which the "b" object is a member (altx), and the name of the "b" object (bName). This name uniquely identifies the relationship between the "a" and "b" objects since a "b" object can

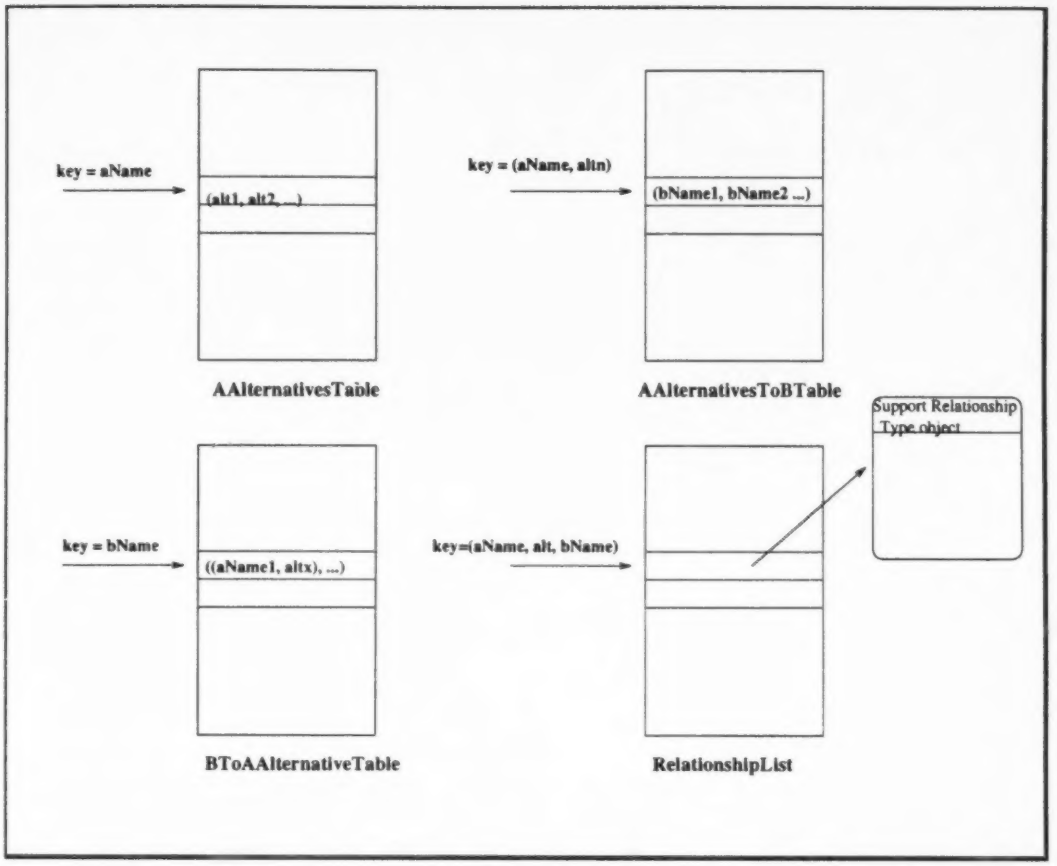

Figure B-2 Design of the Support Relationship Type

exist in more than one sets of the strategic alternatives supporting the same "a" object. Each entry of the *RelationshipList* is a pointer to the Relationship Type object that describes the relationship between the "a" and "b" objects.

The other three class variables of the Support Relationship Type are used to facilitate access to the appropriate entries of the *RelationshipList*. The *AAlternativesTable* allows the retrieval of all alternative sets of supporting objects identified for a given "a" object. The access key to the table is the unique name of the "a" object. Each entry in the table

consists of a list of identifiers, each representing an alternative set of "b" objects. The *AAlternativesToBTable* facilitates the retrieval of all "b" objects in a specific alternative of an "a" object, whereas the *BToAAlternativesTable* facilitates the retrieval of all alternatives of which the "b" object is a member.

Constraint Relationship Type

There are three class variables in the Constraint Relationship Types: namely, *AToBTable*,

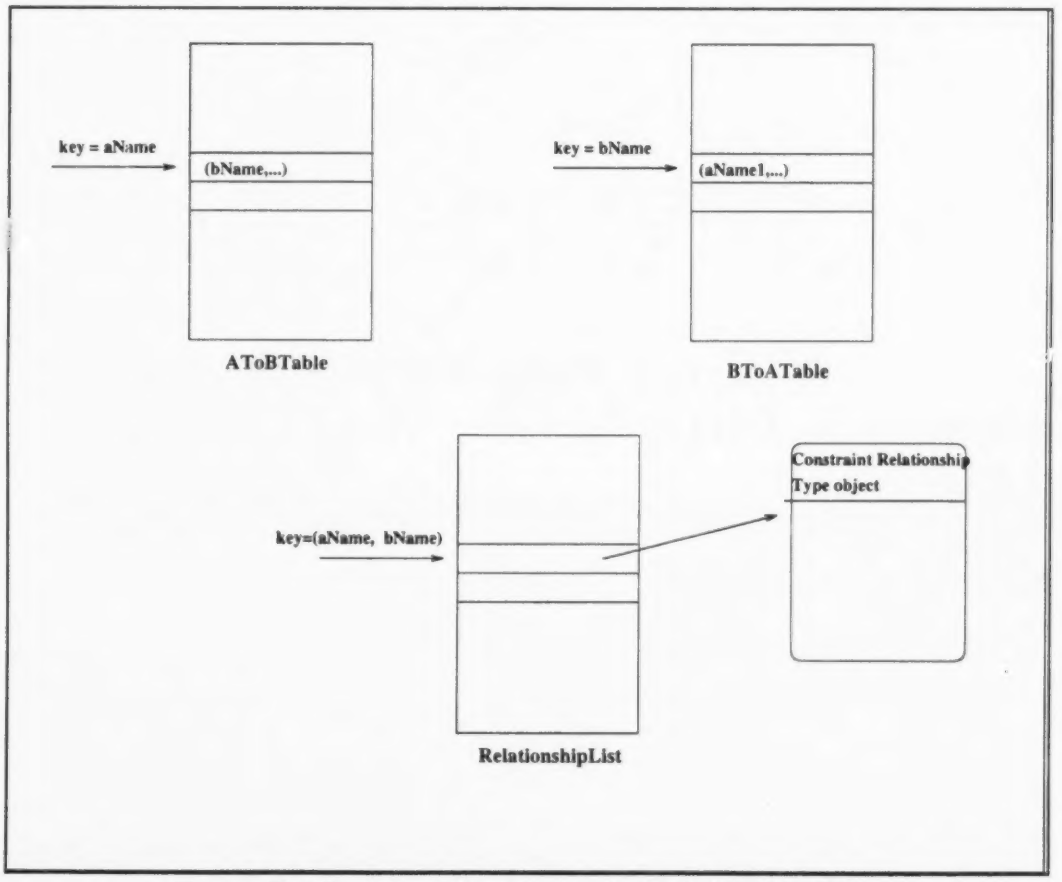

Figure B-3 Design of the Constraint Relationship Type

BToATable and *RelationshipList*. Figure B-3 illustrates the design of the three variables. The design of the *RelationshipList* is similar to that in the Support Relationship Type, except for the format of the access key. Since the relationship does not support alternative sets of "b" objects, the relationships between a unique pair of "a" and "b" objects can be identified by a key made up of the name of the "a" object and "b" object together. The unique identifier or name attribute of the Constraint Relationship Type object is therefore of the form (aName, bName). The *AToBTable* and *BToATable* tables facilitate the access of all "b" objects related to a particular "a" object, and vice versa.

Monitor Relationship Type

Figure B-4 illustrates the 4 class variables in the Monitor Relationship Type. Following the naming convention, the "a" object refers to the Constraint object, the "b" object refers to the Sensor object and the "c" object refers to the Analyzer object. Access to the *RelationshipList* is through the name of the compound key consisting of the name of the "a" and "b" objects. The name of the Analyzer object is stored in the *analyzerName* variable in the Relationship Type object.

Three class variables, the *AToBTable*, *BToATable* and *CToABTable* facilitate the access to the *RelationshipList*. An example is used to visualize the functions of the three variables. When a Sensor object ("b" object) detects a change in the value of its related Data Element object, it triggers its related Analyzer objects to analyze the impact. To do

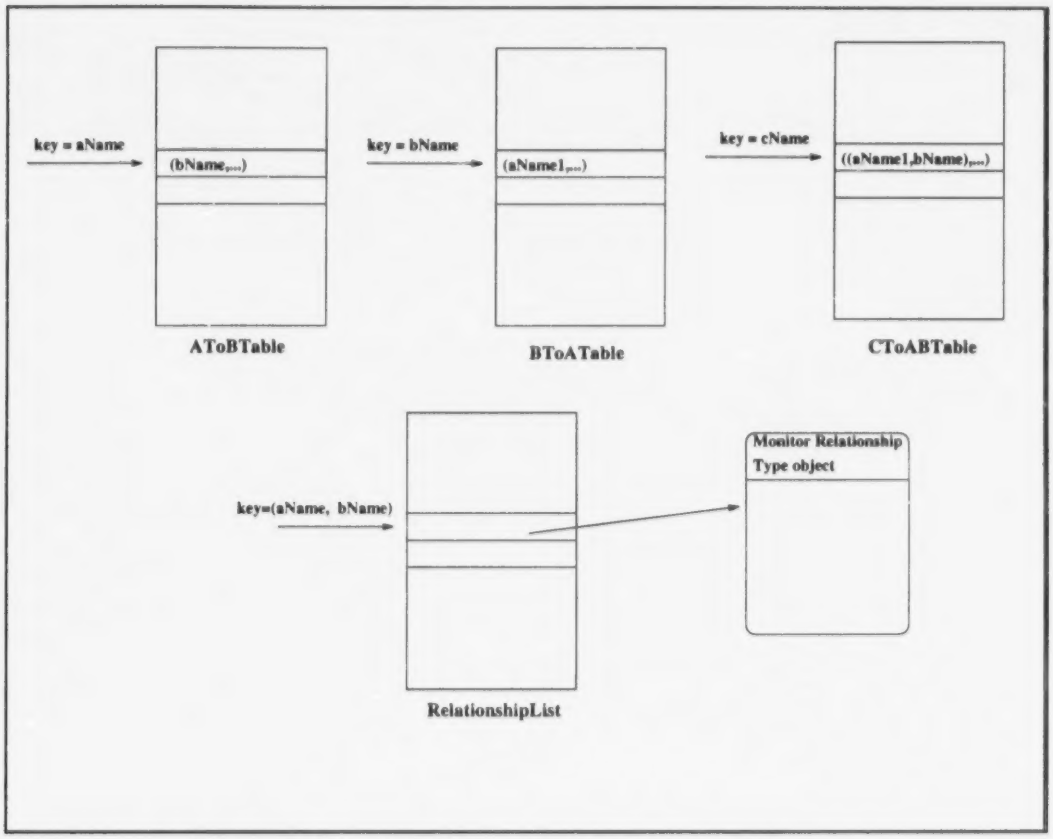

Figure B-4 Design of the Monitor Relationship Type

this, the system needs to access the class variable *BToATable* of the Monitor Relationship Type to retrieve a list of the names of all the Constraint objects ("a" objects) related to the given Sensor object. A list of compound keys is constructed using the name of the "a"objects and the "b" object. This list is then used to retrieve the corresponding Monitor Relationship Type objects from the *RelationshipList*, and the names of the Analyzer objects are retrieved from the *analyzerName* variable of the Monitor Relationship Type objects. A message is sent to each of the Analyzer objects to execute the associated application program. For each of the Analyzer object, if the analysis results in a need to trigger a change in the *constraintStatus* of its related Constraint Object Type, it locates

the related Constraint objects ("a" objects) via the class variable *CToABTable* in the Monitor Relationship Type and sends a change message to the appropriate Constraint objects.

Detect Relationship Type and the Activate Relationship Type

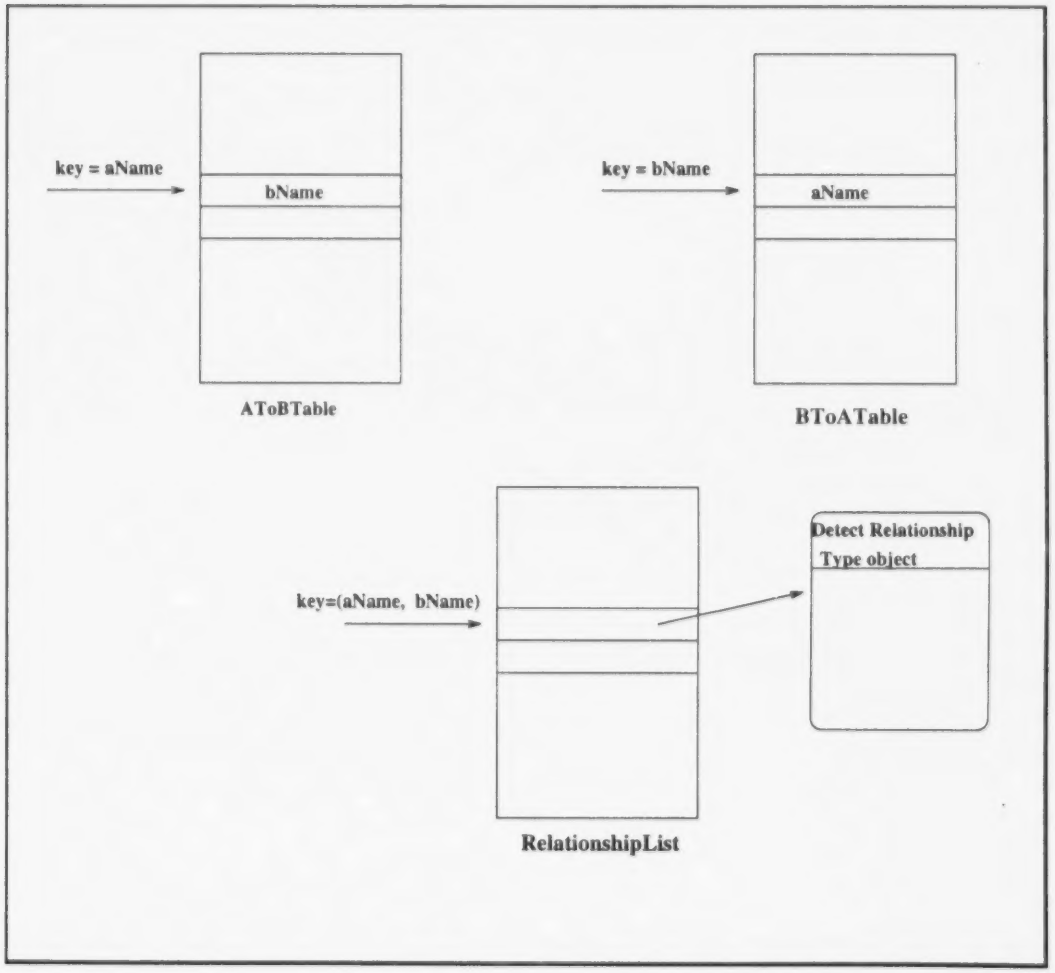

Figure B-5 Design of the Detect and Activate Relationship Types

The design of the Detect Relationship Type and the Activate Relationship Type includes three class variables: namely, the *AToBTable*, the *BToATable* and *RelationshipList*. Figure B-5 graphically illustrates the design of the variables. The key to the *RelationshipList* is the compound key (the name of the relationship) made up of the name of the "a" object (the Sensor object or the Analyzer object) and "b" object (the Data Element object or the Application Program object). The *AToBTable* and *BToATable* variables facilitate the retrieval of the "b" object related to a given "a" object, and vice versa.

Appendix C: Requirements for the RCIM Graphical Browser

authored by Garry Froehlich and Lettice Tse

C.1 Overview

A graphical browser (GB) for the Reactive Corporate Information Model (RCIM) will be built. The GB is meant to ease the display of existing RCIM models. Only the display of two parts of the model will be dealt with: the StrategicPlan objects and Support relationships, and the Constraint objects and Constraint relationships. Separate diagram types are associated with StrategicPlan objects and Constraint objects. The GB will also be integrated with the existing RCIM Editor and the RCIM database.

C.2 Introduction

This document is intended to state the requirements for the GB program. No risk analysis or priority is attached to any of the requirements. The major requirement is outlined and then discussed in detail. Integration issues and other non-functional requirements are also given. Finally, issues that will not be dealt with in this version, but may be important to future versions, are outlined.

C.3 Terms

1. RCIM: Reactive Corporate Information Model.

2. Graphical Browser (GB): The program being created to display parts of the RCIM graphically.

3. RCIM Editor: The existing program for producing the RCIM using dialog boxes and menus.

4. Object: any of the StrategicPlan objects or Constraint objects in the RCIM.

5. Relationship: any Support relationship (connection between StrategicPlan objects) or Contraint relationship (connection between Constraint objects and StrategicPlan objects) in the RCIM.

6. Supporting object: all Support relationships have a source StrategicPlan object and a destination StrategicPlan object. The source object is referred to as the supported object and the destination is referred to as the supporting object.

C.4 Requirements

The major requirement considered in this document is the display of the RCIM model: take an existing RCIM model and display it as a diagram.

There are two types of views for displaying the model.

1. StrategicPlan View: displays all of the StrategicPlan objects and Support relationships

connected below a given root object.

2. Constraint View: displays a single StrategicPlan object and all Constraint objects and Constraint relationships connected to it.

There are no limitations on the number of each type of view that can be opened.

C.5 Display of the Model

1. Each view has a specific look that is to be followed.

2. Each view type has a specific layout associated with it which is to be applied when displaying the model.

3. Any number of views may be open at once. All views should remain consistent with one another.

C.5.1 StrategicPlan View

1. This view displays a root StrategicPlan object and all StrategicPlan objects and Support relationships supporting it. An example is show in Figure C-1. Alternatively, the view may display all StrategicPlan objects in the database, including those which have no Support relationships.

2. The constraints for any StrategicPlan object should be accessible from a StrategicPlan

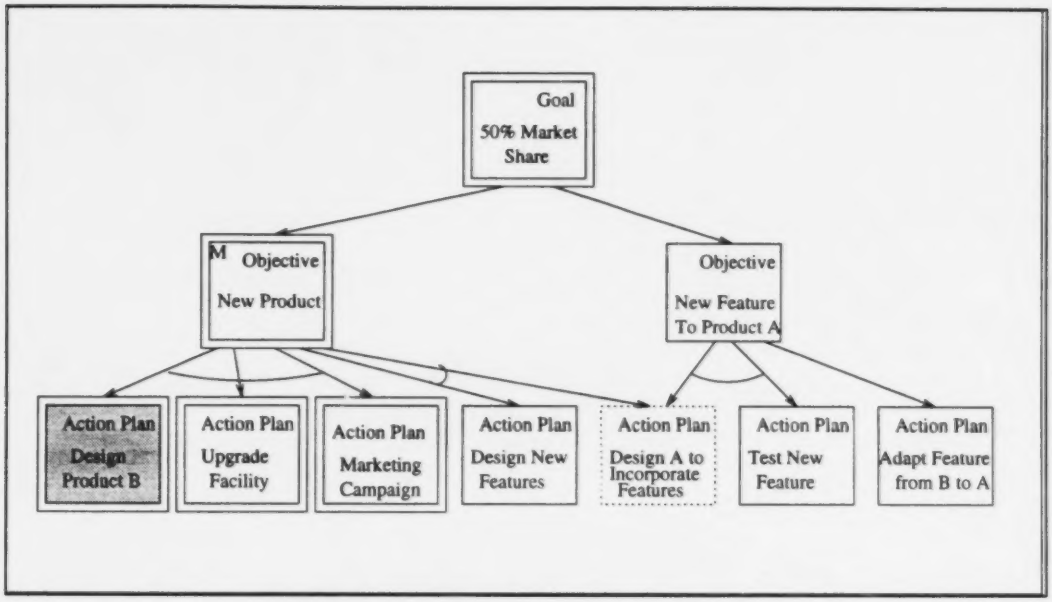

Figure C-1 Example Strategic View

view. A separate Constraint view is brought up for the given StrategicPlan object.

C.5.1.1 Depiction

1. StrategicPlan objects are represented as rectangles. They display their name and their type within the rectangle. Their selection status is indicated by:

not feasible: single dotted line

feasible: single solid line

selected: double solid line

manually selected: double solid line annotated with a capital M.

Their commit status is indicated by:

completed: darkly shaded

not committed: not shaded

committed: lightly shaded

2. Support relationships are represented by a solid line connecting two StrategicPlan objects. Each line is annotated with the percentage contribution of the supporting object.

3. A set of StrategicPlan objects is indicated by an arc connecting all of the relationships between the supported object and the members of the supporting set.

4. A single StrategicPlan object may belong to more than one set.

C.5.1.2 Layout

1. The diagram is laid out in a hierarchical tree structure.

2. The diagram consists of layers of objects with lines (relationships) joining the layers. All Goals, or the root object, is placed in the first layer. Objects (generally CSFs), supporting the Goals (or the root object), are placed in the next layer. Objectives are placed in the next layer, with supporting Objectives placed in the layer below the Objective they support. Finally, Action Plans are placed in the last layer along the bottom of the diagram.

3. Objects within one alternative set should be placed together wherever possible.

C.5.2 Constraint View

This view displays a single StrategicPlan object and all Constraint objects and Constraint

relationships connected to it. An example is shown in Figure C-2.

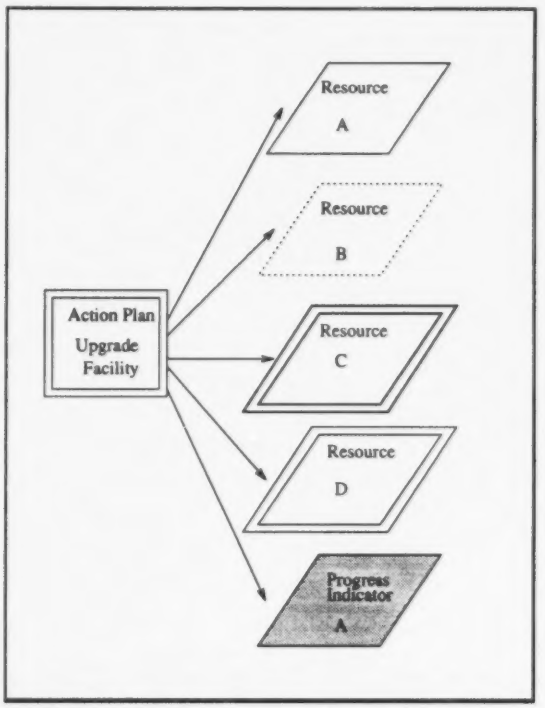

Figure C-2 Example Constraint View

C.5.2.1 Depiction

1. Constraint objects are represented as parallelograms. They display their name and their type within the polygon. Their state is indicated by:

valid - single solid line

invalid - single dotted line, blinking

critical - double bolded line, blinking

warning - double solid line

completed - shaded figure

(The blinking behavior can be turned on and off.)

2. Constraint relationships are represented as a solid line, annotated with the property, if any, of the Constraint relationship.

C.5.2.2 Layout

The StrategicPlan object is displayed, centered on the left of the diagram. Constraint objects are displayed in a vertical column to the right of the StrategicPlan object and each is connected to the StrategicPlan object with a line.

C.6 Integration Issues

1. The GB is initiated by the RCIM Editor.

2. The RCIM Editor is responsible for the integrity of the database.

3. The RCIM Editor contains dialog boxes for editing the attributes of objects and relationships. This functionality remains the same.

4. The GB should not access the database directly, but should do so through the RCIM Editor.

5. All changes made to the database should be reflected in all the diagrams shown by the GB.

C.7 Other Issues

1. Performance: this is not a time critical application. Users should expect a response within a few seconds for editing, and within half a minute for the automated layout, but there are no hard limits.

2. Consistency: creation, modification and removal of all types of objects and relationships should be done consistently from a user perspective.

3. Automatic layout: the layout manager should produce a clean and easily readable layout of the model.

C.8 Future Considerations

1. Expand the Graphical Browser (GB) to a Graphical Editor (GE) to allow the user to add/edit/delete objects and relationships displayed in a diagram. User should also be allowed to undo changes made through the Graphical Editor and have them reflected in the database.

2. Allow users to collapse and expand entire branches of StrategicPlan views to lessen the amount of detail displayed.